Northeast Fisheries Science Center Reference Document 97-05

A Report of the 23rd Northeast Regional Stock Assessment Workshop

23rd Northeast Regional Stock Assessment Workshop (23rd SAW)

Stock Assessment Review Committee (SARC) Consensus Summary of Assessments

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Region
Northeast Fisheries Science Center
Woods Hole, Massachusetts

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This report is a product of the 23rd Northeast Regional Stock Assessment Workshop (23rd SAW). Proceedings and products of the 23rd SAW are scheduled to be documented and released as issues of the *Northeast Fisheries Science Center Reference Document* series. Tentative titles for the 23rd SAW are:

Current resource conditions in Georges Bank and Mid-Atlantic sea scallop populations: results of the 1996 NEFSC sea scallop research vessel survey

Report of the 23rd Northeast Regional Stock Assessment Workshop (23rd SAW): Public Review Workshop

Report of the 23rd Northeast Regional Stock Assessment Workshop (23rd SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments

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MEETING OVERVIEW

The Stock Assessment Review Committee (SARC) meeting of the 23rd Northeast Regional Stock Assessment Workshop (23rd SAW) was held at the Northeast Fisheries Science Center (NEFSC), Woods Hole, Massachusetts during 18-22 November 1996. The SARC Chairman was Dr. Emory Anderson (NEFSC). Members of the SARC included scientists from the NMFS Northeast and Southeast Fisheries Science Centers and the Northeast Regional Office, the Mid-Atlantic and New England Fishery Management Council staffs, the Atlantic States Marine Fisheries Commission (ASMFC), the States of Maryland and Florida, the Canadian Department of Fisheries and Oceans, and the University of Massachusetts (Dartmouth) (Table 1). In addition, more than 30 other persons attended some or all of the meeting (Table 2). The meeting agenda is presented in Table 3.

Table 1. Composition of the SARC.

Chair:
Emory Anderson, NMFS/NEFSC
(SAW Chairman)

Four *ad hoc* experts chosen by the Chair:
Jay Burnett NMFS/NEFSC
Steve Cadrin, NMFS/NEFSC
Ralph Mayo, NMFS/NEFSC
Gary Shepherd, NMFS/NEFSC

One person from NMFS, Northeast Regional Office:
Peter Colosi, NMFS/NER

One person from each Regional Management Council:
Andrew Applegate, NEFMC
Richard Seagraves, MAFMC

Atlantic States Marine Fisheries Commission/State personnel:
Michael Armstrong, FL DEP
John Carmichael, ASMFC
James Uphoff, MD DNR

One or more scientists from:
Canada - **Diane Beanlands, DFO, Dartmouth, NS**
Canada - **Ginette Robert, DFO, Halifax, NS**
Academia - **Alexei Sharov, U Mass, Dartmouth**
Other Region - **Douglas Vaughan, NMFS/SEFSC**

Table 2. List of participants.

National Marine Fisheries Service
Northeast Fisheries Science Center
Frank Almeida
Russell Brown
Steve Clark
David Dow
Wendy Gabriel
Lisa Hendrickson
Josef Idoine
Han-Lin Lai
Shih-Wei Ling
Steve Murawski
Helen Mustafa
Loretta O'Brien
William Overholtz
Paul Rago
Fred Serchuk
Tim Sheehan
Michael Sissenwine
Katherine Sosebee
Mark Terceiro
Susan Wigley
Northeast Regional Office
Dana Hartley

New England Fishery Management Council
Lou Goodreau
Atlantic States Marine Fisheries Commission
Najih Lazar
Massachusetts Div. of Marine Fisheries
Thomas Currier
Xi He
Arnold Howe
Jeremy King
David Pierce
Maine Department of Marine Resources
Daniel Schick
Rhode Island Dept. of Fish and Wildlife
Mark Gibson
Canadian Dept. of Fisheries and Oceans
Chris Annand
Manomet Observatory
Connie Delano Gagnon
Gregg Morris

Table 3. Agenda of the 23rd Northeast Regional Stock Assessment Workshop (SAW-23) Stock Assessment Review Committee (SARC) meeting.

NEFSC Aquarium Conference Room
166 Water Street
Woods Hole, Massachusetts

18 November (1:00 PM) - 22 November (6:00 PM) 1996

AGENDA

TOPIC	SUBCOMMITTEE & PRESENTER	SARC LEADER	RAPPORTEUR
MONDAY, 18 November (1:00 PM - 5:00 PM)......			
Opening Welcome Agenda Conduct of Meeting		E. Anderson, Chairman	H. Mustafa
Goosefish (Monkfish) (A)	Southern Demersal W. Gabriel	A. Applegate	J. Idoine
TUESDAY, 19 November (9:00 AM - 5:00 PM)......			
Continue Goosefish			
Sea Scallop (B)	Invertebrate P. Rago	G. Robert	L. Hendrickson
WEDNESDAY, 20 November (9:00 AM - 5:00 PM)......			
Continue Sea Scallop			
Bluefish (C)	Coastal/Pelagic W. Overholtz	D. Vaughan	M. Terceiro
SOCIAL at the Andersons' (7:00 PM)			
THURSDAY, 21 November (9:00 AM - 5:00 PM)......			
Continue Bluefish			
Review Goosefish Advisory Report			
Review Sea Scallop Advisory Report			
Review Bluefish Advisory Report			
Review Available SARC Report Sections			
FRIDAY, 22 November (9:00 AM - 5:00 PM)......			
Review all Research Recommendations			
Complete SARC Report Sections			
Complete Advisory Report Sections			
Review List of Publications for the SAW-23 Series			
Other Business			H. Mustafa

Opening

Dr. Emory Anderson introduced the members of the SARC, and Dr. Michael P. Sissenwine, NEFSC Science and Research Director, welcomed Committee members and visitors.

Dr. Sissenwine thanked the participants for their interest in the SAW process and gave a brief overview of the significance of the SAW process. The Region had been engaged in the SAW process for many years. It was unique in that it was a collaborative effort among the stakeholders, interested scientists, and the NEFSC, where the process was considered to be very important and of high priority. As the demand for stock assessment advice continued to grow and the challenges increase, it was important to maintain commitment to the process. The high degree of demand for scientific advice at this time was such that we sometimes wonder if we are victimized or blessed. Unlike the theory of the "donor push", while elsewhere interested scientists are looking for clients, we do not suffer that problem whatsoever. In our case, the "user pull" far exceeded the "donor push". The positive aspects of all this, of particular significance to scientists, were the huge challenges of great demands, challenges for building expertise to meet expectations. We continue to grow and evolve to meet the challenges in the process.

Dr. Anderson briefly reviewed the SAW process and the responsibilities of its components. This "circular" process, a partnership between science and management, continuously evolves to provide sound review of advice for fisheries management. Assessments presented to the SARC are prepared in Subcommittees. The SARC itself is a peer-review body which reviews and revises the work of the Subcommittees and prepares advice for presentation at sessions of the SAW Public Review Workshop held during meetings of the two Regional Fishery Management Councils. The SAW Steering Committee is the "glue" holding the parts of the process together. Its function is largely oversight, but provides guidance, determines species to be reviewed, and sets terms of reference for each review. The Steering Committee includes the Executive Directors of the two Regional Management Councils and ASMFC, as well as the NMFS Northeast Regional Administrator and Science and Research Director. The process draws on scientists from the above organizations, agencies outside the Northeast region, academia, as well as Canada. It is a totally open process where industry participation is also encouraged.

The Chairman reminded SARC members that they had been invited to participate because of their expertise and were expected, to the extent possible, to attend the entire meeting. He indicated that he expected everyone to participate in the discussions and ask questions.

It was noted that the SAW Steering Committee would meet in December to address the issue of increasing demand for assessment information and the need to modify the SAW process to better handle this demand. Any thoughts or ideas on the part of SARC meeting participants would be welcome. If time permitted, the Chairman would hold a discussion on the topic later in the meeting.

Agenda and Reports

The SARC agenda was noted as being unique in containing only three species. For many participants, however, the meeting workload would be as heavy or heavier than at other times. The agenda included goosefish (monkfish), sea scallop, and bluefish in the Northeast Region (Table 3). A chart of US commercial statistical areas used to report landings in the Northwest Atlantic is presented in Figure 1.

The SARC reviewed a total of six working papers. Three papers were recommended for publication in the NEFSC Reference Document series (Table 4). Subcommittee reports were prepared from three meetings (Table 5) and were the basis of the species sections in this report. A draft "SARC Consensus Summary of Assessments" and a draft "Advisory Report on Stock Status" would be provided to members of the SAW Steering Committee and circulated prior to the SAW-23 Public Review Workshop sessions. The final reports would be published in the NEFSC Reference Document Reference series.

Table 4. NEFSC Reference Documents associated with the 23rd Northeast Regional Stock Assessment Workshop (23rd SAW).

Current resource conditions in Georges Bank and Mid-Atlantic sea scallop populations, Results of the 1996 NEFSC sea scallop research vessel survey by H.-L. Lai and L. Hendrickson
Report of the 23rd Northeast Regional Stock Assessment Workshop (23rd SAW), Stock Assessment Review Committee (SARC) Consensus Summary of Assessments
Report of the 23rd Northeast Regional Stock Assessment Workshop (23rd SAW), Public Review Workshop

Highlights of Presentations and Discussion

Species Presentations

In addition to discussing a multitude of technical aspects of assessment methods and calculations, the need for more sampling and an improvement in the quantity and quality of data available for assessments was emphasized to some extent for each species considered and was reflected in the research recommendations in the species sections of this report. The need for representative sampling over the range of all the species and over all fisheries was emphasized in the discussion of goosefish. Relative to scallops, the use of Canadian survey data was considered for filling the

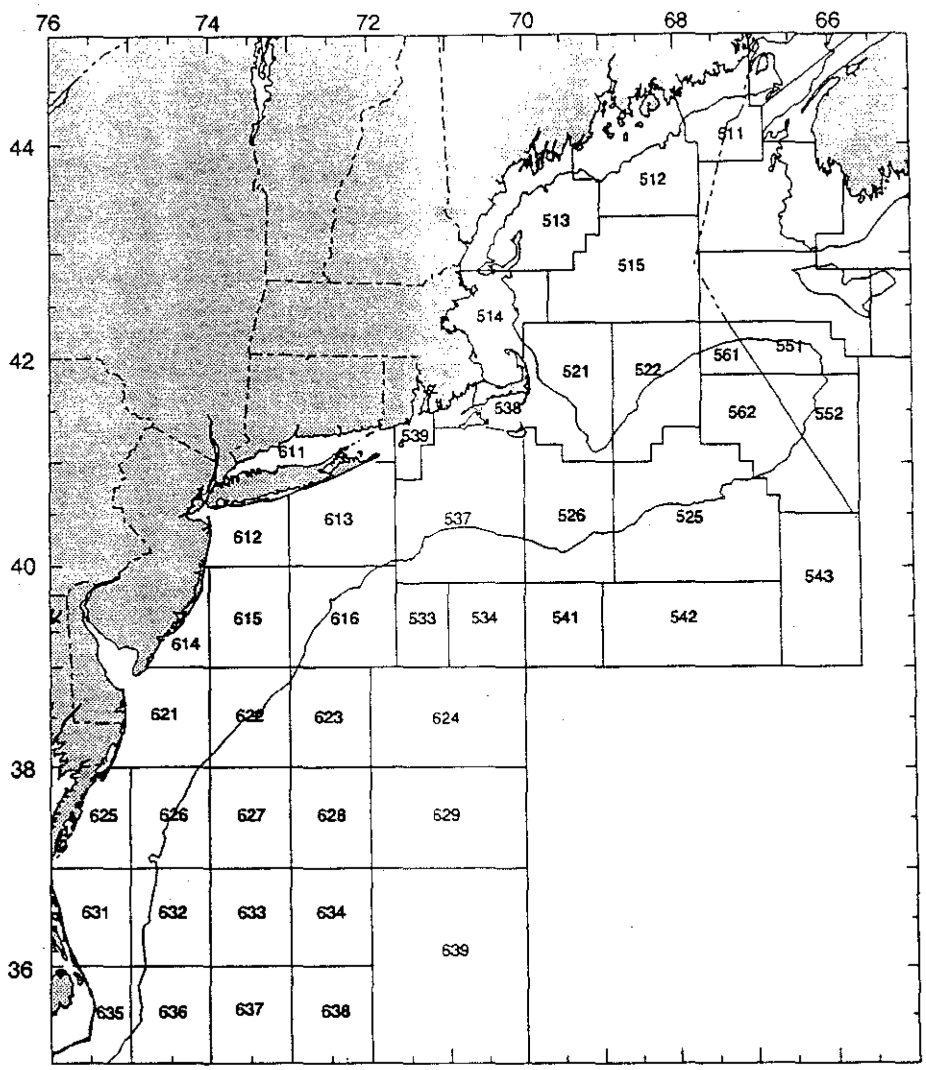

Figure 1. Statistical areas used for catch monitoring in offshore fisheries in the Northeast United States.

Table 5. SAW-23 Subcommittee meetings.

Subcommittee - Topic Participation		Meeting Date and Place
Southern Demersal Subcommittee - GOOSEFISH		22-23 October 1996 Woods Hole, MA
S. Cadrin, NMFS/NEFSC	W. Ling, NMFS/NEFSC	
W. Gabriel, NMFS/NEFSC (Chair)	P. Rago, NMFS/NEFSC	
D. Hartley, NMFS/NERO	R. Seagraves, MAFMC	
J. Idoine, NMFS/NEFSC	K. Sosebee, NMFS/NEFSC	
N. Lazar, ASMFC	M. Terceiro, NMFS/NEFSC	
Invertebrate Subcommittee - SEA SCALLOP		4-8 November 1996 Woods Hole, MA
S. Cadrin, NMFS/NEFSC	P. Kostovik, NMFS/NEFSC	
S. Correia, MA DMF	H.-L. Lai, NMFS/NEFSC	
L. Goodreau, NEFMC	P. Rago, NMFS/NEFSC (Chair)	
W. DuPaul, VIMS	D. Schick, ME DMR	
S. Edwards, NMFS/NEFSC	R. Taylor, Gloucester, MA	
L. Hendrickson, NMFS/NEFSC		
Coastal/Pelagic Subcommittee - BLUEFISH		7 November 1996 Wakefield, RI
J. Carmichael, ASMFC	J. Mason, NY DEC	
V. Crecco, CT DEP	C. Moore, MAFMC	
M. Gibson, RI DFW	W. Overholtz, NMFS/NEFSC (Chair)	
N. Lazar, ASMFC	M. Terceiro, NMFS/NEFSC	

data gaps created by the lack of sampling on the Northeast Peak of Georges Bank. The historically low intensity of biological sampling of the commercial and coast-wide recreational bluefish fisheries was thought to have worsened in recent years.

Regarding goosefish, some discussion centered on methods for the identification of stock mixing and conversion coefficients; methods were reviewed to estimate length at full recruitment. Some of the views raised during these discussions are reflected in the research recommendations for the various species.

In the discussion of the modified DeLury model and swept-area calculations for sea scallops, it was recommended that total mortality values be calculated from the survey. An evaluation of the relationships between exploitation estimators was performed, and annual differences in vulnerability patterns in relation to the timing of the implementation of various management measures was examined. There was some discussion of the possible reopening of the Georges Bank closed areas to scalloping. Concern was expressed that when if and when such areas were reopened, they could be quickly depleted because of a shift in fishing effort from areas of current low abundance.

Regarding bluefish, there was a brief review of estimates of fishing mortality and stock size based on analyses of the American Littoral Society angler tagging data and a multiple tuning index, modified DeLury model. Since neither of these two analyses had been thoroughly reviewed by the Coastal/Pelagic Subcommittee, the results were considered to be preliminary. Relative to the decline in bluefish abundance, the two working papers containing these analyses were considered valuable as a basis for developing hypotheses to be explored at a future time. One of the working papers, "Evidence of offshore displacement of Atlantic coast bluefish based on commercial landings and fishing effort" by V.A. Crecco, discussed the hypothesis that adult bluefish have shifted their distribution offshore in recent years. The other working paper, "Data snooping in response to SAW TOR D for bluefish: identify possible causes for the decline in bluefish abundance" by M. Terceiro, investigated the relationships among several factors that might influence bluefish distribution and abundance.

Status of Vessel Trip Data

During the meeting, Mr. Peter Colosi (NMFS/NER) was asked to update the status of the processing of the Northeast Regional vessel logbook data.

Stage 1 and 2 audit

Data received from UNICOR are parsed into new record structures. During this process, vessel identifiers are validated. An audit is also run to ensure that all records (trip, gear, and species) are properly created.

Stage 3 audit

Data from all trips are checked for proper codes, values within range, and consistent and valid dates. Data and images with identified errors are accessed and all fields are checked on those reports.

1994 sea scallop audit

All identified scallop trips, both dredge and trawl, were audited by directly comparing the image of the log to the keypunched data. Select fields (area, gear, and mesh) were highlighted for special attention during this process. These trips were also run through the standard Stage 3 audit.

1994 audit

The NEFSC completed an initial audit of all trips based on data entered by UNICOR. Subsequent to this, the logs were scanned and indexed by the NER. As this process was occurring, reports with multiple trips and trips with multiple or mixed areas, gears, and mesh sizes were flagged. Trips with catches of herring, squid, and mackerel and incomplete species or dealer information were also identified. These trips were later reviewed and edited as necessary, regardless whether they were identified by the Stage 3 audit as having an error.

For all trips, a Stage 3 audit was completed. During this process, approximately 40% of the reports were flagged by the audit as having a fatal error. A fatal error is defined as an error (as described above) in one of the following fields: date sailed, date sold, date landed, loran, latitude, longitude, area, gear code, species code, quantity kept or discarded, dealer number, or port and State landed. The images and data from these reports were retrieved and the data edited as necessary. Reports which were flagged with only an informative error were not audited. An informative error is an error in the following fields: number of hauls, tow/soak time, gear size, and gear quantity. The following fields are not checked: number of crew or anglers, depth, time sailed or landed, and operator name and number. If a report contained a fatal error, all data on that report were reviewed.

Trips which did not contain an error have not been retrieved. These trips will be individually reviewed and edited following the completion of the 1994 and 1995 Stage 3 audits. This is expected to begin in the spring of 1997.

1995 audit

Trips from January through May, received as of July 18, 1996, have been run through a Stage 3 audit. Trips received subsequent to that date and all trips for the remainder of the year are currently undergoing the auditing process. This has flagged about 30% of the reports for correction. The audit process is the same for 1995 as described for 1994.

1996 data and audit

As noted in Table 6, data for trips during January-October 1996 have been 95% entered. While these data have not been run through the Stage 3 audit, some quality checks are being made. After the data have been entered, vessel and dealer identifiers are validated. Other fields (area, gear, and species codes)

Table 6. Status of vessel trip data.

Time period	Data entry source	No. of trips[2]	Data entry status	Audit status	Estimated completion date
May-Dec 1994	UNICOR[1]	89,400	Complete	Scallop trips - side-by-side audit complete	Complete
				All trips - Stage 3 audit run. Final clean up in progress. Stage 3 will be rerun on all trips including scallop trips	Jan 31, 1997
Jan-May 1995	NER	47,600	Complete	Initial Stage 3 audit run on all trips. Will be rerun along with remainder of year	Complete
Jun-Nov 1995	UNICOR	106,800	Complete	Stage 3 audit in progress	Feb 28, 1997
Dec 1995	NER	9,200	Complete		
Jan-Oct 1996	NER	126,300[3]	95% complete[3]	Data quality audits in place (vessel ID, area, gear, species)	Data entry: Mar 31, 1997
Nov-Dec 1996	NER	11,300[3]	31% complete[3]	Stage 3 will begin in April 1996	Stage 3 audit: Aug 1997

are checked against look-up tables containing valid codes. After completion of the 1994 and 1995 audits, 1996 data will go through the standard Stage 3 audit. It is expected that all data entry will be completed by March 1997 and all auditing by August 1997.

Dealer reports (weighouts)

Preliminary 1996 dealer data are available through October for all states except Rhode Island and New York. Data for these latter states are partially available. All 1996 data have received preliminary audit in port offices. Final audits and creation of master files have not been accomplished.

Vessel and dealer system redesign

The NER is in the process of procuring an optical character recognition system to be used in processing vessel trip report (VTR) data. If this system is implemented, only slight changes in the reporting form will occur at that time. These changes will be intended to provide industry with an easier reporting vehicle and increase the accuracy of data capture from the logs. These steps should improve the overall quality of the VTR data.

During 1997, it is intended that a system evaluation and, as necessary, a redesign be conducted. The ultimate goal of this task will be to design a commercial fishery data collection system which meets the needs and concerns of industry while providing NMFS and other users with the data they require. This process will include the input of all groups involved in the collection and use of commercial fisheries data in the Northeast. Due to the lead time required to make any necessary regulatory changes, the task must be completed by early fall 1997.

This review and potential redesign will provide an opportunity to change the data elements which are collected through both the vessel and dealer systems. An opportunity may also be available to modify other systems which collect fishery-dependent data.

It should be noted that there are several other coastwide programs now underway whose goals are similar to those of this task. It is intended that, to the extent possible, all of these efforts will work together and that the Northeast effort will take advantage of work already accomplished by these other programs.

Discussion of the SAW Process

On Wednesday morning of the SARC meeting, three hours were devoted to a discussion of the SAW process. To facilitate discussion, the Chairman had distributed a list of problems and potential solutions associated with the SAW process which would be discussed at the SAW Steering Committee meeting in December. The SARC discussion was extremely productive, with many useful ideas raised. An expanded list of problems and solutions prepared following this discussion is given in Table 7.

Table 7. Summary of SAW process discussion.

Problems

- Growing demand for more assessment advice
- Overlap in SARC, Council Monitoring Committee, and ASMFC Technical Committee responsibilities
- ASMFC peer-review needs
- Demands for more "independence of peer review"
- Inadequate data
- Insufficient assessment expertise and participation at State level
- Insufficient NEFSC expertise on Council Monitoring Committees and ASMFC Technical Committees
- Inadequate access to Federal data bases by experts outside NEFSC
- Problematic or poorly-understood analytical models and complicated reports
- Inadequate linkage between advice and implementation
- National concerns
- Assessment of US-Canada transboundary stocks

Potential Solutions

- Expand/extend present two 1-week SARC meetings per year
- Provide multi-year advice (e.g., surfclams, ocean quahogs, summer flounder, and others)
- Distinguish routine updates from "benchmark" assessments
- Broaden meeting participation
  - Industry participation/representation on Subcommittees and SARC
  - Academic/scientific consultant participation on Subcommittees and SARC
  - Expertise from abroad
  - Financial support for academics/consultants
  - Federal/ASMFC financial support to States earmarked for hiring assessment experts
  - Greater State/Council/academic access to Federal data bases
  - Shorter and more understandable technical reports
  - Rotation of venues for Subcommittee meetings
  - Greater involvement of field biologists, relevant graduate students, economists, oceanographers, etc.
- Bring all ASMFC peer reviews into the SAW process
- Divide responsibilities among SARC, Council Monitoring Committees, and ASMFC Technical Committees
- Delegate more responsibility to Subcommittees (first drafts of advice, concise summaries)
- Speed up SARC meetings
  - Shorter terms of reference for species
  - Allocate less time for discussion per stock
  - Implement policy of accepting/rejecting, but not redoing assessments
- Peer review by correspondence (e.g., journal process)
- Greater NEFSC participation on Council Monitoring Committees and ASMFC Technical Committees
- Address concerns/problems with assessment methodology
  - "Primers" or "cookbooks" of assessment methods
  - Reconstitute Assessment Methods Subcommittee and name new Chairman
- Greater adherence to policy of distributing Subcommittee documents 2 weeks in advance of SARC meetings
- Coastwide SAW process

A. GOOSEFISH

Terms of Reference

The following terms of reference were addressed for goosefish:

a. Evaluate the consistency between proposed assessment and management areas using available information on stock structure.

b. Evaluate estimates of fishing mortality rates and stock abundance trends including estimates of precision.

c. Assess current stock status relative to the proposed overfishing definitions and other biological reference points (i.e., $F_{0.1}$, F_{MAX}, $F_{70\text{-}79}$, and survey relative biomass thresholds and targets).

d. Recommend a comprehensive program of research and monitoring with the objective of improving the quality and precision of estimates of fishing mortality, stock biomass, and recruitment for the species.

Introduction

Goosefish (*Lophius americanus*) are currently managed through regulations implemented on a state-by-state basis. The States of New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, and New Jersey require a minimum tail length of 11 inches and a maximum ratio of liver weight to tail weight landed per trip of 25%. Draft Amendment 9 to the Multispecies Fishery Management Plan to regulate goosefish is undergoing public hearings as part of the development of joint New England Fishery Management Council (NEFMC) - Mid-Atlantic Fishery Management Council (MAFMC) regulation of goosefish in the Exclusive Economic Zone (EEZ).

The overfishing definition for goosefish was developed by a technical working group of Council and NEFSC scientists, modified slightly by the NEFMC, and certified by the NEFSC Science and Research Director:

"Monkfish in the northern and southern management areas are defined as being overfished when the three-year moving average autumn survey weight per tow falls below the 33rd percentile of the time series, 1963-1994, or when fishing mortality exceeds $F_{threshold}$. Monkfish are in danger of becoming overfished when the three-year moving average autumn survey weight per tow falls below the median of the three-year moving average during 1965-1981 and when fishing mortality is between F_{target} and $F_{threshold}$.

For the northern and southern areas, $F_{threshold}$ is based on conditions of stock stability at high abundance, calculated at the fishing mortality rate that prevailed during 1970-1979. F_{target} for the southern area is $F_{0.1}$. For the northern area, F_{target} is currently undefined."

Definition of Stock Components

Data to definitively distinguish separate stock units of goosefish are currently unavailable. Assessment units described at SAW-14 (NEFSC 1992) are based on groups of survey and statistical areas, and are continued with minor modification in this assessment (Table A1).

Recruitment patterns differ substantially between the Gulf of Maine and Mid-Atlantic regions. Inspection of length frequency data from southern research survey strata indicate strong modal peaks associated with the appearance of a strong year class in fall 1972. In 1973 and 1974, the peaks appeared as successively higher length frequencies in the south, but were not present in northern strata during those years (Figures A1 and A2). Strong modal peaks appeared for small-sized fish in the northern strata in 1990 and 1993 (spring) and persisted briefly in that region in subsequent years, but did not appear in the southern strata. Although it could be argued that recent lower stock sizes in the southern area may have precluded a similar large recruitment event in that region, the example in the 1970s was based on abundance levels which were relatively unaffected by regional patterns in fishing pressure (Table A2, Figure A3).

The differential spatial distribution of these year-class events indicate recruitment is not uniform over the range of the species. This is consistent with regional circulation patterns: the Gulf of Maine may serve as a larval retention area, as most water within the Gulf circulates in a counterclockwise gyre from the Scotian Shelf onto and around Georges Bank (e.g., as summarized in Mountain 1991). The boundary between the western Gulf of Maine and the eastern New England Shelf has, however, been characterized as "leaky" by Limeburner and Beardsley (1982). Water flowing south and southwestward from the Gulf of Maine mixes with Nantucket Sound water and continues west along the New England Shelf. Thus, it is possible that, depending on timing and location of spawning in the Gulf of Maine, some recruitment may be advected south from the Gulf as eggs or larvae. More detailed analysis of spatial coherence of recruitment patterns may refine these inferences.

As discussed at SAW-14, summaries of distribution patterns from research vessel survey data indicate that few goosefish are present along the center axis of Georges Bank (Figures A4 - A6). Consistent with the relatively closed circulation patterns in the Gulf of Maine, this region may serve as a working boundary of convenience to separate fish distributions regionally. The patterns of distribution are likely to be influenced seasonally by temperature, however (NEFSC 1992), and fish from both the northern and southern edges of Georges Bank may mix through the Great South Channel at depth during the summer.

Different maturity rates by area cannot be identified because comparable data sets are unavailable. A study by Armstrong *et al.* (1992) of maturity rates of fish distributed south of Cape Cod was based on samples collected between 1982-1986 (Table A3, taken from Hartley 1995). A subsequent study by Almeida *et al.* (1995) for a comparable region, but including fish from a wider time span (1975-1986 and 1991-1992) indicated lower values of L_{50} from that region. It currently cannot be determined if this is a reflection of density-dependent response through the inclusion of fish collected during recent periods of high exploitation/low stock abundance. In the north, studies of maturity have been based on data collected in 1975-1986, 1992, and 1992-1993. Values of L_{50} from studies undertaken in recent years indicated a downward trend over time, presumably related to changes in stock abundance. Thus, the effects of different regional patterns in exploitation/abundance history cannot be separated from potential effects of separate stock structure for studies based on recently-collected data.

Identification of differential growth rates by area is similarly problematic. A study of growth rates developed by Armstrong *et al.* (1992) for fish collected south of Cape Cod was based on data collected in 1982-1986. These data were collected 6-10 years before the data used by Hartley (1995, MS) in developing growth rate estimates for fish in the Gulf of Maine. Different growth models were also used by the two investigators, which further complicated direct comparisons of rates.

Comparisons of spawning seasons described by Armstrong *et al.* (1992) and Hartley (1995, MS) were based on definitions of ranges of spawning times rather than peaks. Although potential differences may reflect regional temperature dependency rather than separate spawning contingents, they may also reflect differential changes in size composition of spawners by area as a function of exploitation.

Because substantial portions of data support neither separate nor combined biological definitions of stock units, and because other supporting data (e.g., genetic data, tagging and migration studies) are absent, there can be no definitive resolution to the issue of stock structure for goosefish at this time. Because recruitment patterns differ significantly between areas, however, information is retained by continuing to summarize assessment information by area.

The southern deepwater extent of the range of goosefish overlaps with the northern extent of the range of blackfin goosefish (*Lophius gastrophysus*) (Caruso 1983). The importance of this taxonomic problem in the identification of landings from the southern extent of the range of goosefish is also unknown, but is believed to be small.

There is some mismatch between some proposed management areas and assessment areas developed at SAW-14 and continued here. However, if few fish are distributed within the center of Georges Bank, the mismatch may not be critical for a portion of the

Bank. Explicit implications of any mismatches will depend on the final placement of the management boundary and associated measures to be implemented.

Fishery Data

US Landings

Landings statistics for goosefish are sensitive to conversion from landed weight to live weight because most landings have occurred as tails only (or other parts). The conversion of landed weight of tails to live weight of goosefish in the NEFSC weighout database is made by multiplying landed tail weight by a factor of 3.32. Since initial inspection of this database indicated that, in 1980, reported live weight equaled reported landed weight of tails, it was assumed that values for 1980 had not been converted to live weight. Table A2 reflects this adjustment. Landings by area were not available in final form for 1994-1995. Consequently, allocations between areas in those years should be considered preliminary in all landings tables.

The National Marine Fisheries Service Statistics Division reports total landings of goosefish as the sum of landings reported through the NEFSC weighout system, landings data collected by port agents for ports not included in the weighout system, and landings reported by States not included in the weighout system. (Within the NEFSC, the latter two components of landings have historically been known as "general canvas" data.) The NMFS Statistics Division summary of data from all sources is reported as Oracle Table GENCAN. These total summary statistics are reported in Table A2 with the heading "General Canvas." For these data, landings are usually assumed to be reported in the database as live weight. For goosefish, however, landings as reported in the GENCAN database were lower than those reported in the weighout database for 1964-1985. It appears that a conversion from landed to live weight was not made for those years. An initial adjustment is made in Table A2. For 1986-1989, a conversion factor of 2.57 had been used to generate estimates in the GENCAN database of live weight from landings, but for consistency, a conversion factor of 3.32 was implemented over the time series in Table A2. All landings of goosefish are reported in the GENCAN data as "unclassified tails." Consequently, some landed weight attributable to livers may be inappropriately converted to live weight. Because statistical areas are not associated with all landings reported through this system, landings were assigned to northern or southern regions, depending on the State of landing. Because Massachusetts borders on both northern and southern regions, Massachusetts landings were split between regions based on areas associated with weighout landings in that year.

Total landings (live weight) remained at low levels until the middle 1970s, increasing from hundreds of metric tons (mt) to around 6,000 mt in 1978 (Table A2). Landings remained stable at between 8,000 and 10,000 mt until the late 1980s. After 1989, landings increased to a peak level of 26,400 mt in 1995. By region, landings began to increase in the north in the mid-1970s and began to increase in the south in the late 1970s. Most of the increase in landings in recent years has been from the southern region.

Patterns of total landings are driven primarily by landings of goosefish tails. From 1964 to 1972, the only recorded parts were tails (unclassified). Much of the fish caught went to shack until the mid-1970s. From 1964 to 1975, landings of tails rose from 19 mt to 643 mt (landed weight, Table A4). Those landings then increased to 2,302 mt in 1980 and 4,541 mt in 1991. On a regional basis, most tails were landed from the northern component in the 1960s (75-90%) through to the late 1970s (74% in 1978) (Tables A5 and A6). From 1979 to 1989, landings of tails were about equal from both regions. In the 1990s, landings from the south began to predominate and provide over 60% of the tails.

Several market categories were added to the system in 1982 (Table A4). Tails were divided into large (> 2.0 lbs), small (0.5-2.0 lbs), and unclassified categories. At the same time, livers began being sold. In 1989, unclassified round fish were added and in 1991, peewee tails (< 0.5 lbs) and cheeks appeared. Finally, in 1992, bellyflaps were also recorded.

The increase in landings of livers is especially notable, increasing steadily from 1982, when 10 mt were landed, to almost 460 mt in 1994. During that time, ex-vessel prices for livers rose from an average of $0.97/lb to over $5.00/lb, with seasonal variations as high as $19.00/lb. For whole or unclassified round fish, landings have averaged over 440 mt during 1991-1993. In 1994, preliminary estimates of landings of round fish rose to over 2,000 mt. The relatively large rise in the tonnage of peewee tails landed is also significant. The increase from 37 mt in 1991 to 258 mt in 1994 (at < 0.5 lb per tail) represents a large increase in numbers of fish landed, most of which are below L_{50} in terms of maturity.

Landings (landed mt) by these individual market categories by region are shown in Tables A5 and A6. Landings by region in 1994-1995 are based on preliminary divisions of total landings between northern and southern regions based on historical average ratios by market category and will be updated as area-specific information becomes finalized.

Canadian Landings

Landings (live wt) from Canadian waters (NAFO Subdivision 5Zc) are shown in Table A2 and Figure A3. Data are only available from 1986 onwards, but show a rapid rise from about 340 mt in 1986 to a peak of over 1,550 mt in 1990. In more recent years, annual landings declined to around 400-500 mt.

Trends in Stock Abundance from Research Survey Indices

Research survey indices were standardized to adjust for statistically significant effects of trawl type and vessel on catch rates as noted below.

Effect	Coefficient	Source
Trawl	Weight: 0.2985 Number: 0.4082	Sissenwine and Bowman (1977)
Vessel	Weight: not significant Number: 0.83	NEFSC (1991)

A systematic review of the applicability of these coefficients may lead to future revisions of these indices, however.

To describe and compare modal patterns in length frequency data between surveys more easily, an "ageing" convention was developed based on consensus and knowledge of growth patterns in the Gulf of Maine region (Figure A7). Length at age may be higher in the southern region, based on higher average water temperatures and earlier commencement of spawning. This convention applies to this report only, for preliminary descriptive purposes.

Northern Region

Indices from NEFSC autumn research trawl surveys indicated that biomass fluctuated without trend between 1963 and 1975, appeared to have increased briefly in the late 1970s, but declined thereafter to low levels in the 1990s (Table A7, Figure A8). While the point estimate of biomass in 1995 (1.71 kg/tow) is the highest observed since 1986, it is well below even the 1963-1975 mean (2.44 kg/tow). Abundance in numbers (Table A7, Figure A9) may have declined during the early 1960s, but fluctuated without trend until the late 1980s. Since 1989, abundance in numbers has increased to the highest levels observed in the time series.

Indices from the NEFSC spring research trawl surveys reflect similar trends of relatively high biomass levels in the mid-1970s (but with possible declines in the late 1970s) and a declining trend from the early 1980s to the lowest values in the time series in 1992 (Table A8, Figure A10). As in the autumn survey series, abundance in numbers fluctuated until the early 1980s (Figure A11). After 1987, numbers trended upwards to some of the highest levels observed in the time series.

Other indices are available from survey series covering shorter periods of time and/or more restricted areas. The NEFSC Gulf of Maine summer survey is based on a series of fixed stations on trawlable bottom rather than randomly stratified stations. It indicates no trend in biomass or abundance during 1991-1995, although patterns may be masked by very large confidence intervals around estimates in the first two years (Table A9, Figures A12 and A13). Abundance indices from the NEFSC sea scallop survey are based on a few strata on the Northern Edge of Georges Bank rather than over the entire Gulf of Maine. Thus, the interpretation of that index may be one of consistency with the overall regional pattern of increased abundance in recent years (Table A10, Figure A14), although only a small portion of the region is included in the index. (No time series of biomass indices is available from this survey.) The ASMFC shrimp survey likewise may show a trend of increasing abundance during 1989-1996 (Table A11, Figures A15 and A16). Values for 1987 have large confidence intervals, and values for 1988 are missing, however.

Length distributions have become increasingly truncated over time (Figure A1, Figures A17 and A18). By 1990, fish > 80 cm in length were uncommon in length frequency distributions, and by 1996, fish > 60 cm had become relatively uncommon as well. Although recent length frequency distributions indicate a fairly high abundance of small fish, few of those modes can be followed more than two years.

Several modes potentially representing strong year classes have appeared consistently in survey distributions in recent years. Following the "ageing" convention in Figure A7, a 1989 year class appeared in the autumn survey in 1990 at 15-17 cm, persisted in the spring, shrimp, scallop, and inshore summer surveys in 1991 as modes near 20 cm, and may have appeared in the autumn survey in 1991 as a mode near 25 cm. Identification of this mode at lengths above 25 cm in 1992-1993 surveys would require additional separation of the year class by direct ageing. However, it is possible that this cohort may have contributed to a slight rightward shift in regional length compositions in subsequent years. A 1990 year class appeared less consistently, emerging in the shrimp and autumn surveys as a mode above 20 cm in 1992. A 1992 year class appeared in the 1993 scallop, summer, shrimp, and autumn surveys as modes under 20 cm, and in the same surveys in 1994 as modes just above 20 cm. A potential 1993 year class was observed at age 1 in the 1994 autumn survey, was not identifiable in other surveys that year, but may have appeared as modes above 20 cm in the 1995 surveys. No modes corresponding to a 1994 year class appeared in any 1995 surveys. Modes in 1996 summer surveys near 20 cm especially would require direct ageing in order to identify the year class, but are lower than modes associated with small fish in previous years. There appears to be a slight rightward shift in length distribution in the 1996 summer surveys, perhaps related to a possible contribution by the 1993 year class. Preliminary indices of abundance in 1996 indicate lower recruitment levels than observed in the early 1990s.

Some differences in patterns of abundance between surveys may arise due to different gear efficiencies and areal coverage. It is clear, however, that recent increases in numbers of fish at small sizes in this region have not lead to accumulated biomass in following years, especially when length compositions are compared to length compositions from surveys in earlier years.

Southern Region

Biomass indices from the NEFSC autumn research survey declined rapidly in the second half of the 1960s and fluctuated at stable levels until the early 1980s (Table A12, Figure A19). In the mid-1980s, biomass levels declined and have remained at low levels since 1987. Abundance in numbers has shown similar declines after the mid-1960s, with a spike in 1972, slight increases in the late 1970s - early 1980s, and a decline thereafter (Figure A20). In recent years, abundance in numbers has fluctuated without trend at low levels.

Similar trends are observed from NEFSC spring research survey data. Stock levels remained fairly high during the mid 1970s - early 1980s, but declined to record-low levels in the late 1980s and have remained there in recent years (Table A13, Figures A21 and A22).

Indices based on the NEFSC winter survey appear to have fluctuated without trend, consistent with the lack of a trend in other surveys (Table A14, Figures A23 and A24). Indices based on the NEFSC sea scallop survey, although appearing to increase over the 1984-1996 period, do not cover a period of time during which other longer time series showed contrast in abundance levels (Table A15, Figure A25).

Length distributions from this region show increasing truncation over time, reflected in declines in minimum, mean, and maximum length over time (Figures A26 and A27) and length frequency distributions (Figure A2). Maximum lengths declined by approximately 20 cm or more over the time series.

The 1986 year class could be followed as its mode increased from 14 cm in the 1987 scallop survey to 19-20 cm in the 1987 autumn trawl survey, and through the 1988 and 1989 spring, scallop, and autumn surveys (Figure A2). The 1990 year class appeared strong in the 1991 scallop survey as a mode near 16 cm, in the 1991 autumn survey as a mode near 20 cm, and in the 1992 winter survey as a mode near 25 cm. The 1992 year class appeared strong in the 1993 scallop survey (at 17 cm), somewhat strong in the 1993 autumn survey (near 19 cm), and strong in the 1994 winter (near 25 cm) and 1994 autumn surveys (near 29 cm). The 1993 year class showed a similar pattern in the following years. The 1994 year class, by comparison, appears smaller than the preceding two year classes, based on the 1995 scallop survey (15-17 cm) and the 1996 winter survey. The 1995 year class likewise appears relatively weak, compared to recent years, based on the 1996 scallop survey.

As in the northern region, recent year class events are rarely observable in survey length frequency distributions at lengths > 40 cm. Currently, fish > 60 cm are rare, especially when compared to the 1960s. Any recent strong recruitment events do not appear to live long enough to contribute substantially to increased stock biomass.

Spawning Stock Biomass Indices from Survey Length Composition Data

The survey indices were used to develop an index of spawning stock biomass (SSB). Composite length frequencies, based on a five-year summation of catch per tow at length, $\bar{I}(L,t)$, were multiplied by predicted eggs at length, Egg(L), and the fraction mature, [PMAT(L)]. The computational formula is:

$$SSB(t)=\sum_{L} SSB(L,t)=\sum PMAT\ (L)*Eggs(L)*\bar{I}(L,t)$$

where

$$PMAT\ (L)\ =\ \frac{1}{1+e^{\,13.9568-0.03862325L}}$$

where

$$L=length(mm)$$

and

$$Eggs\ (L)=0.0683\ L^{3.74}$$

Parameters for PMAT(L) were derived by fitting the logistic function to derived percentiles of fraction mature described in Hartley (1995). The fecundity-length relationship was obtained from Armstrong (1987).

Results for the indices of spawning stock biomass (Figure A28) mirror the progressive decline in mean length. To the extent that spawning stock biomass levels in 1970-1979 represent a relatively unfished population, contemporary spawning stock biomass levels are 32% of the 1970-1979 average level in the northern area and 16% in the south (Table A16).

Currently, about 12% of the SSB is produced by fish less than L_{99}. In the north, about 11-13% of the egg production is by the partially mature component of the length distribution (Figure A28). In the south, 17-30% of the SSB is from the partially mature component of the length distribution.

Estimation of Fishing Mortality Rates

Instantaneous total mortality rates (Z) for goosefish were estimated using a length-based method by Beverton and Holt (1956):

$$z\ =\ \frac{K(L_{\infty}-\bar{L})}{(\bar{L}-L')}$$

where K and L_{∞} are from von Bertalanffy growth models and $\bar{L}$ is the mean length of individuals in the region (as stratified delta mean catch per tow at length, adjusted for trawl and vessel effects, when significant). L′ is the smallest fully recruited length and was estimated from inspection of LOWESS smoothed length frequency data (Cleveland 1979).

Parameter	North	South
L_∞	126.0 cm	129.2 cm
K	0.1080	0.1198
L′	59 cm	19 cm

Estimates of Z by area and year and minimum 95% confidence intervals are presented in Tables A17 and A18 and Figures A29 and A30. The standard deviation of the mean length (above L′) was used to develop a standardized normal distribution with mean 0 and standard deviation 1. The truncated distribution was rescaled so that unit area was obtained between the values of the standardized normal distribution corresponding to $L = L'$ and $L = L_\infty$. The median of the resulting distribution and boundaries of 95% of the distribution were estimated conditional on given values of L_∞, K, and L′. The corresponding range in Z thus does not reflect variance contributed by error in estimation of L_∞, K, or L′ nor any covariance among terms. These estimates should be considered minimum estimates of the potential range in Z.

In the north, estimates of instantaneous total mortality increased from an average of 0.25 during 1970-1979 to 0.35 in 1991-1995. If instantaneous natural mortality (M) is assumed to equal 0.2, instantaneous fishing mortality (F) would equal 0.05 in 1970-1979 and 0.15 in 1991-1995. In the south, estimates of Z increased from an average of 0.34 during 1970-1979 to 0.71 in 1991-1995. If M = 0.2, then F = 0.14 during 1970-1979 and 0.51 in 1991-1995.

Results of this approach were similar to those obtained by the technical working group (TWG) even though the statistical methodology differed somewhat:

Approach	Region	F_{70-79}	F_{90-94}	F_{91-95}
TWG[1]	North	0.05	0.17	
	South	0.22	0.45	
SARC	North	0.05	0.16	0.15
	South	0.14	0.46	0.51

[1]From memorandum dated February 12, 1996.

The differences are attributable to different input data and statistical techniques. The input data sets in this analysis differ from those used by the TWG because strata sets were finalized and standardization coefficients were incorporated in the SARC analysis. The analytic methodology differed between the two sets of estimates as well: the TWG used a linear regression technique (Wetherell *et al.* 1987), while the SARC used the Beverton-Holt method based on mean length.

Evaluation of Stock Status with Respect to Reference Points

Northern Region

Based on the criteria in the proposed overfishing definition, goosefish in the northern region are overfished. Estimates of current fishing mortality rates of 0.15 (Table A17, 1991-1995 average, assuming a natural mortality rate of 0.2) are in excess of the estimate of $F_{Threshhold}$ of 0.05 (1970-1979 average), although current rates are not precisely estimated. The current three-year moving average catch per tow (kg/tow from NEFSC offshore autumn research vessel surveys) of 1.243 kg/tow is below the 33rd percentile of the 1963-1994 series, 1.460 kg/tow (Table A19), the level below which overfishing is defined to occur. The moving average has been below the 33rd percentile since 1989, and is well below the target of 2.496 kg/tow (median of three-year moving average during 1965-1981).

Estimates of current fishing mortality rates were evaluated with respect to preliminary estimates of $F_{0.1}$. as reported in the Public Hearing document. $F_{0.1}$ = 0.09 for the northern area. Current estimates of fishing mortality of 0.15 are imprecise, with an upper 95% confidence interval likely above 0.45. Estimation procedures for yield-per-recruit-based reference points should be reviewed and revised, e.g., as new data become available on weight at age of the catch and partial recruitment.

Southern Region

Based on the criteria in the proposed overfishing definition, goosefish in the southern region are overfished. Estimates of current fishing mortality rates of 0.51 (Table A18, 1991-1995 average, assuming a natural mortality rate of 0.2) are substantially in excess of the estimate of $F_{Threshhold}$ of 0.14 (1970-1979 average). The current three-year moving average catch per tow (kg/tow from NEFSC offshore autumn research vessel surveys) of 0.430 is below the 33rd percentile of the 1963-1994 series, 0.750 kg/tow (Table A19), the level below which overfishing is defined to occur. The moving average has been below the 33rd percentile since 1987, and is well below the target of 1.848 kg/tow (median of three-year moving average during 1965-1981).

Estimates of current fishing mortality rates were evaluated with respect to preliminary estimates of $F_{0.1}$, as reported in the Public Hearing document. $F_{0.1} = 0.1$ for the southern area, and current estimates of fishing mortality of 0.51 are substantially above that level. Estimation procedures for yield-per-recruit-based reference points should be reviewed and revised, e.g., as new data become available on weight at age of the catch and partial recruitment.

SARC Comments

The SARC discussed methods to identify the degree of mixing over the range of the species. For goosefish, the use of tagging studies is limited more by capture and handling stress than by tagging technology. Scallop survey data indicate that summer concentrations of goosefish on Georges Bank remain primarily along the northern and southern edges rather than extending across the center of the Bank. Concentrations are more continuous at depth from north to south through the Great South Channel. Because egg veils and larvae remain in the water column for up to three months, advection can lead to recruitment in areas far from the location of spawners. The SARC noted that spawning effort in the western Gulf of Maine could contribute to recruitment in the eastern Gulf of Maine or in southern areas.

The SARC noted that foreign removals from southern areas were likely substantial before 1976, but were not recorded by species either because of low rates of occurrence relative to other species or because species-specific reporting systems were not in place.

The SARC concluded that when the current survey standardization analyses indicated significant differences in catch rates between vessels in terms of numbers but not weight, it was not appropriate to incorporate the non-significant weight conversion factor. The SARC recommended review of conversion coefficients on a species-by-species basis to provide additional information on the applicability of conversion coefficients.

The SARC reviewed several methods of estimating length at full recruitment used in length-based assessment methods. The piecewise regression approach has the advantage of being objective, reproducible, and consistent with estimates approximated from LOWESS smoothing. When year-class strength has been increasing, as in the northern area, length at full recruitment is difficult to estimate using any method, however. The SARC recommended the use of a fixed length at full recruitment over the entire time series to address this problem, recognizing that as the fishery shifts to smaller fish or as fishing intensity increases, the estimated length at full recruitment will decrease. Under those conditions, the fixed length would provide an estimate of mortality of the larger-sized component of the population. Differences in length at full recruitment by area are likely to arise if recruitment patterns vary by area, if historical levels of exploitation vary by area, or if survey catchability varies by area. Since all these conditions may differ between the northern and southern areas, the SARC recommended the use of different lengths at full recruitment for the northern and southern estimates.

Because size distributions become increasingly truncated as exploitation increases, the number of data points available to fit a regression estimator of mortality (e.g., Wetherell *et al.* method) decreases over time. For the northern area where survey catches are already relatively low, this has the effect of generating estimates of slopes and subsequent estimates of mortality with larger confidence intervals, and in some cases, providing unreasonably low point estimates of mortality. Consequently, the SARC recommended the use of a Beverton-Holt estimator (which relies only on a single mean length estimate annually) and recommended averaging over the past five years to smooth interannual variability in survey catch at length.

The SARC recommends significant upgrades in the quality and quantity of data collected for this species, especially in the area of biological sampling. Data collection should emphasize representative sampling over the range of the species and over all fisheries.

Research Recommendations

- Updated data for the estimation of life history parameters (growth, maturity, sex ratio) by area over the range of the species distribution to improve the accuracy of growth curve parameters which affect mortality and spawning stock estimates and to develop a basis for stock separation.

- Improved biological sampling of landings and discards of tails, whole, and gutted fish, including the collection of vertebrae for ageing whenever possible to characterize the age and length structure of removals from the population.

- Validated historical time series of landings by area, market category, and data source; development of improved estimates of landings by area for 1994-1995 as data become available; and development of a protocol for future proration methods when area and market category information is incomplete to estimate removals as commercial landings.

- Development of a target study to estimate discards and discard mortality by fishery to estimate the amount of removals as discard.

- Evaluation of the utility of survey standardization coefficients for goosefish.

- Extension of current surveys or initiation of supplementary surveys to evaluate the distribution and characteristics of goosefish occurring in water deeper than standard survey strata.

- Collection of fecundity data (by area, over the range of the species) to characterize spawning potential as a function of size structure.

- Estimation of the proportion of livers landed without tails. If proportion is significant, develop relationships between liver weight landed and size and numbers of individuals removed to estimate removals as landings.

- Integration of information from Canadian landings data, biological sampling, and research survey programs to characterize removals from the northern region landed in Canada.

- Evaluation of the suitability of research surveys by States for inclusion in assessment analyses to characterize the distribution and characteristics of inshore components of the population.

- Identification of location and timing of spawning over the range of the species, including evaluation of egg and larval survey data to develop a basis for stock separation and to improve the evaluation of time/space management measures.

- Initiation of genetic studies, morphometric studies, parasite studies, and/or elemental analyses to develop basis for stock separation.

- Continuation and expansion of trophic studies to estimate the potential effects of cannibalism and predation on natural mortality rates by size and age.

- Definition of the distribution of egg veils and larvae in time and space using oceanographic circulation models to improve understanding of recruitment dynamics and to develop a basis for stock separation.

- Extension and expansion of historical landing series to estimate foreign and historically unreported removals.

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Table A1. Research survey strata and statistical areas associated with northern and southern stock assessment regions.

Survey	Northern area	Southern area
NEFSC offshore bottom trawl	20-30, 34-40	1-19, 61-76
ASMFC shrimp	1-12	
Shellfish	49-54, 65-68, 71-72, 651, 661	1-48, 55-64, 69-70, 73-74, 621, 631
Statistical areas	511-515, 521-523, 561	524-526, 562, 537-543, 611-636

Table A2. USA landings (calculated live weight, mt) of goosefish as reported in NEFSC weighout database [North = SA 511-523, 561; South = SA 524-639 excluding 551-561; Other = SA 500, 520 or 000 (1994)]; North Carolina DMF; Canada (NAFO Area 5Zc); Adjusted General Canvas database (See text. North = ME, NH, northern weighout proportion of MA; South = Southern weighout proportion of MA, RI-VA); 1964-1994. NC and Canadian data use different conversion factors, e.g. NC landings include expanded liver weights.

	Weighout Database						Adjusted General Canvas Database		
Year	North	South	Other	Total	North Carolina	Canada	North	South	Total
1964	45	19	0	64	N/A	N/A	45	61	106
1965	37	17	0	54	N/A	N/A	37	79	115
1966	299	13	0	312	N/A	N/A	299	69	368
1967	539	8	0	547	N/A	N/A	540	59	598
1968	451	2	0	453	N/A	N/A	449	36	485
1969	258	4	0	262	N/A	N/A	240	43	283
1970	199	12	0	211	N/A	N/A	199	53	251
1971	213	10	0	223	N/A	N/A	213	53	266
1972	437	24	0	461	N/A	N/A	437	65	502
1973	710	139	0	848	N/A	N/A	708	240	948
1974	1,197	101	0	1,297	N/A	N/A	1,200	183	1,383
1975	1,853	282	0	2,134	N/A	N/A	1,877	417	2,294
1976	2,236	428	0	2,663	N/A	N/A	2,256	608	2,865
1977	3,137	829	0	3,965	1	N/A	3,167	1,314	4,481
1978	3,889	1,338	0	5,227	46	N/A	3,976	2,073	6,049
1979	4,014	3,372	0	7,386	162	N/A	4,068	4,697	8,765
1980	1,113	1,188	0	2,302	283	N/A			
1980[1]	3,695	3,949	0	7,675		N/A	3,623	6,035	9,658
1981	3,217	2,274	1	5,492	106	N/A	3,171	4,142	7,313
1982	3,860	3,658	6	7,524	64	N/A	3,757	4,492	8,249
1983	3,849	4,086	0	7,935	29	N/A	3,918	4,707	8,624
1984	4,202	3,610	0	7,812	89	N/A	4,220	4,171	8,391
1985	4,616	4,107	0	8,722	155	N/A	4,452	4,806	9,258
1986	4,327	3,954	0	8,280	83	339	4,322	4,264	8,586
1987	4,960	3,706	0	8,666	56	748	4,995	3,933	8,926
1988	5,066	4,483	0	9,549	112	909	5,033	4,775	9,809
1989	6,391	8,296	0	14,687	57	1,176	6,232	8,678	14,910
1990	5,802	7,142	0	12,944	62	1,554			
1991	5,693	9,800	0	15,494	65	1,015			
1992	6,923	13,925	0	20,848	17	469			
1993	10,645	15,061	0	25,706	37	352			
1994	2,733	5,323	14,889	22,945	152	541			
1994[2]	9,164	13,781	0	22,945					
1995[3]	14,575	11,839	-	26,414	243	419			

[1] 1980 landed weight as reported in WOLANDS80 database equaled 1980 live weight. If expansion factor were applied to landed weight, revised (higher) weights may be obtained. [2] 1994 landings from unreported statistical areas (000) prorated by average ratio of landings from the two areas 1989-1993. [3] 1995 landings split north and south as canvas data, assume 500 mt landed round in CT, and MA landings split north and south by average 1989-1993 ratio, by market category.

Table A3. Table 4.2 in Hartley (1995). *Description of previous maturity studies of goosefish and the current investigation. Areas are from Cape Cod and the southern portion of Georges to North Carolina (south), and the northern edge of Georges Bank and the Gulf of Maine (north). Lengths are reported in millimeters.*

Area	*Study*	*Collection dates*	*Length at L_{50}*	
			Females	*Males*
South	*Armstrong et al., 1992*	*1982-1986*	*485*	*369*
	Almeida et al., 1995	*1975-1986, 1991 & 1992*	*424*	*371*
North	*NEFSC, 1992*	*1992*	*378*	*314*
	Almeida et al., 1995	*1975-1986*	*462*	*433*
	This study [Hartley 1995]	*1992-1993*	*361*	*320*

Table A4. Landed weight (mt) of goosefish by market category for 1964-1995 for combined assessment areas (SA 511-636), NEFSC weighout database.

Year	Belly flaps	Cheeks	Livers	Gutted	Round	Tails unc.	Tails large	Tails small	Tails peewee	All tails
1964	0.0	0.0	0.0	0.0	0.0	19.3	0.0	0.0	0.0	19.3
1965	0.0	0.0	0.0	0.0	0.0	16.1	0.0	0.0	0.0	16.1
1966	0.0	0.0	0.0	0.0	0.0	93.9	0.0	0.0	0.0	93.9
1967	0.0	0.0	0.0	0.0	0.0	164.8	0.0	0.0	0.0	164.8
1968	0.0	0.0	0.0	0.0	0.0	136.6	0.0	0.0	0.0	136.6
1969	0.0	0.0	0.0	0.0	0.0	79.1	0.0	0.0	0.0	79.1
1970	0.0	0.0	0.0	0.0	0.0	63.5	0.0	0.0	0.0	63.5
1971	0.0	0.0	0.0	0.0	0.0	67.1	0.0	0.0	0.0	67.1
1972	0.0	0.0	0.0	0.0	0.0	139.0	0.0	0.0	0.0	139.0
1973	0.0	0.0	0.0	0.0	0.0	255.5	0.0	0.0	0.0	255.5
1974	0.0	0.0	0.0	0.0	0.0	390.7	0.0	0.0	0.0	390.7
1975	0.0	0.0	0.0	0.0	0.0	642.8	0.0	0.0	0.0	642.8
1976	0.0	0.0	0.0	0.0	0.0	802.2	0.0	0.0	0.0	802.2
1977	0.0	0.0	0.0	0.0	0.0	1,194.4	0.0	0.0	0.0	1,194.4
1978	0.0	0.0	0.0	0.0	0.0	1,574.5	0.0	0.0	0.0	1,574.5
1979	0.0	0.0	0.0	0.0	0.0	2,224.7	0.0	0.0	0.0	2,224.7
1980	0.0	0.0	0.0	0.0	0.0	2,302.4	0.0	0.0	0.0	2,302.4
1981	0.0	0.0	0.0	0.0	0.0	1,654.2	0.0	0.0	0.0	1,654.2
1982	0.0	0.0	10.2	0.0	0.0	2,059.8	153.1	53.3	0.0	2,266.2
1983	0.0	0.0	11.6	0.0	0.0	2,009.9	241.4	138.6	0.0	2,390.0
1984	0.0	0.0	25.0	0.0	0.0	2,121.6	186.8	44.5	0.0	2,352.9
1985	0.0	0.0	28.0	0.0	0.0	2,467.0	86.7	73.4	0.0	2,627.1
1986	0.0	0.0	36.3	0.0	0.0	2,365.4	76.4	52.2	0.0	2,494.0
1987	0.0	0.0	54.2	0.0	0.0	2,463.7	139.9	6.7	0.0	2,610.3
1988	0.0	0.0	112.8	0.0	0.0	2,646.3	195.1	34.8	0.0	2,876.2
1989	0.0	0.0	146.3	0.0	15.6	3,501.8	557.4	360.0	0.0	4,419.2
1990	0.0	0.0	179.7	0.0	217.7	2,601.8	854.1	377.4	0.0	3,833.3
1991	0.0	8.6	270.3	0.0	415.4	2,229.1	1,661.9	614.1	36.6	4,541.6
1992	0.2	3.7	321.5	0.0	386.0	2,778.7	1,908.1	1,293.0	183.3	6,163.1
1993	0.0	1.7	459.9	98.2	528.7	3,503.2	1,933.0	1,851.1	262.4	7,549.8
1994	0.0	5.3	456.5	1,427.1	2,044.7	1,256.9	2,229.5	2,060.8	258.0	5,805.2
1995[1]	2.3	1.0	500.1	2,763.1	2,652.6	895.6	2,524.6	2,424.4	363.5	6,208.1

[1]Values for 1995 are from WORAW95ALL.

Table A5. Landed weight (mt) of goosefish by market category for 1964-1995 for northern assessment area (SA 511-523 and 561), NEFSC weighout database.

Year	Belly flaps	Cheeks	Livers	Gutted	Round	Tails unc.	Tails large	Tails small	Tails peewee	All tails
1964	0.0	0.0	0.0	0.0	0.0	13.5	0.0	0.0	0.0	13.5
1965	0.0	0.0	0.0	0.0	0.0	11.0	0.0	0.0	0.0	11.0
1966	0.0	0.0	0.0	0.0	0.0	90.1	0.0	0.0	0.0	90.1
1967	0.0	0.0	0.0	0.0	0.0	162.5	0.0	0.0	0.0	162.5
1968	0.0	0.0	0.0	0.0	0.0	135.9	0.0	0.0	0.0	135.9
1969	0.0	0.0	0.0	0.0	0.0	77.8	0.0	0.0	0.0	77.8
1970	0.0	0.0	0.0	0.0	0.0	59.8	0.0	0.0	0.0	59.8
1971	0.0	0.0	0.0	0.0	0.0	64.1	0.0	0.0	0.0	64.1
1972	0.0	0.0	0.0	0.0	0.0	131.6	0.0	0.0	0.0	131.6
1973	0.0	0.0	0.0	0.0	0.0	213.8	0.0	0.0	0.0	213.8
1974	0.0	0.0	0.0	0.0	0.0	360.4	0.0	0.0	0.0	360.4
1975	0.0	0.0	0.0	0.0	0.0	558.0	0.0	0.0	0.0	558.0
1976	0.0	0.0	0.0	0.0	0.0	673.4	0.0	0.0	0.0	673.4
1977	0.0	0.0	0.0	0.0	0.0	944.7	0.0	0.0	0.0	944.7
1978	0.0	0.0	0.0	0.0	0.0	1,171.4	0.0	0.0	0.0	1,171.4
1979	0.0	0.0	0.0	0.0	0.0	1,209.1	0.0	0.0	0.0	1,209.1
1980	0.0	0.0	0.0	0.0	0.0	1,113.1	0.0	0.0	0.0	1,113.1
1981	0.0	0.0	0.0	0.0	0.0	969.0	0.0	0.0	0.0	969.0
1982	0.0	0.0	10.0	0.0	0.0	1,145.6	15.0	2.0	0.0	1,162.6
1983	0.0	0.0	9.3	0.0	0.0	1,152.3	4.8	2.4	0.0	1,159.4
1984	0.0	0.0	14.7	0.0	0.0	1,261.9	3.7	0.0	0.0	1,265.6
1985	0.0	0.0	11.4	0.0	0.0	1,385.9	1.6	2.6	0.0	1,390.2
1986	0.0	0.0	13.7	0.0	0.0	1,302.7	0.3	0.2	0.0	1,303.2
1987	0.0	0.0	24.0	0.0	0.0	1,491.5	1.7	0.7	0.0	1,493.9
1988	0.0	0.0	47.4	0.0	0.0	1,516.9	5.6	3.3	0.0	1,525.8
1989	0.0	0.0	58.7	0.0	11.2	1,464.5	327.0	130.2	0.0	1,921.6
1990	0.0	0.0	77.9	0.0	30.3	1,173.7	410.7	154.0	0.0	1,738.4
1991	0.0	3.3	70.0	0.0	0.3	1,013.9	538.6	153.2	9.1	1,714.8
1992	0.0	0.7	83.0	0.0	0.1	910.5	589.9	505.4	79.4	2,085.3
1993	0.0	0.6	208.3	98.2	350.6	1,034.3	867.9	1,061.8	102.9	3,067.0
1994[1]	0.0	1.6	164.8	632.1	621.1	489.4	958.6	817.6	92.5	2,358.1
1995[2]	1.0	0.8	190.7	936.7	732.6	209.0	1,744.4	1,590.4	303.9	3,847.7

[1]Values for 1994 are prorations of total landings in CFDETS94 based on the average, by market category, during the period 1989-1993, of landings from northern and southern assessment area (value for gutted is based on ratio of known statistical areas). [2]Values for 1995 are landings from WORAW95ALL [northern = (ME, NH and part of MA); southern = (part of MA and RI-VA)]. MA landings were partitioned by averages, by market category, from CFDETS89 - 93 known statistical areas.

Table A6. Landed weight (mt) of goosefish by market category for 1964-1995 for southern assessment area (SA 524-636 excluding 561), NEFSC weighout database.

Year	Belly flaps	Cheeks	Livers	Gutted	Round	Tails unc.	Tails large	Tails small	Tails peewee	All tails
1964	0.0	0.0	0.0	0.0	0.0	5.7	0.0	0.0	0.0	5.7
1965	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	5.0
1966	0.0	0.0	0.0	0.0	0.0	3.8	0.0	0.0	0.0	3.8
1967	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	2.3
1968	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.6
1969	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	1.2
1970	0.0	0.0	0.0	0.0	0.0	3.7	0.0	0.0	0.0	3.7
1971	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	3.0
1972	0.0	0.0	0.0	0.0	0.0	7.4	0.0	0.0	0.0	7.4
1973	0.0	0.0	0.0	0.0	0.0	41.7	0.0	0.0	0.0	41.7
1974	0.0	0.0	0.0	0.0	0.0	30.3	0.0	0.0	0.0	30.3
1975	0.0	0.0	0.0	0.0	0.0	84.8	0.0	0.0	0.0	84.8
1976	0.0	0.0	0.0	0.0	0.0	128.8	0.0	0.0	0.0	128.8
1977	0.0	0.0	0.0	0.0	0.0	249.6	0.0	0.0	0.0	249.6
1978	0.0	0.0	0.0	0.0	0.0	403.1	0.0	0.0	0.0	403.1
1979	0.0	0.0	0.0	0.0	0.0	1,015.6	0.0	0.0	0.0	1,015.6
1980	0.0	0.0	0.0	0.0	0.0	1,189.3	0.0	0.0	0.0	1,189.3
1981	0.0	0.0	0.0	0.0	0.0	685.0	0.0	0.0	0.0	685.0
1982	0.0	0.0	0.2	0.0	0.0	912.4	138.1	51.3	0.0	1,101.8
1983	0.0	0.0	2.3	0.0	0.0	857.7	236.6	136.2	0.0	1,230.5
1984	0.0	0.0	10.3	0.0	0.0	859.7	183.1	44.5	0.0	1,087.3
1985	0.0	0.0	16.7	0.0	0.0	1,081.1	85.1	70.8	0.0	1,236.9
1986	0.0	0.0	22.6	0.0	0.0	1,062.6	76.1	52.0	0.0	1,190.8
1987	0.0	0.0	30.2	0.0	0.0	972.2	138.2	6.0	0.0	1,116.4
1988	0.0	0.0	65.4	0.0	0.0	1,129.3	189.5	31.5	0.0	1,350.4
1989	0.0	0.0	87.6	0.0	4.5	2,037.4	230.4	229.8	0.0	2,497.5
1990	0.0	0.0	101.8	0.0	187.3	1,428.1	443.4	223.4	0.0	2,094.9
1991	0.0	5.2	200.2	0.0	415.1	1,215.2	1,123.3	460.9	27.5	2,826.8
1992	0.2	3.0	238.5	0.0	385.9	1,868.2	1,318.3	787.6	103.9	4,077.9
1993	0.0	1.1	251.5	0.0	178.1	2,468.9	1,065.1	789.3	159.4	4,482.8
1994[1]	0.0	3.6	291.7	795.0	1,423.6	767.4	1,270.9	1,243.2	165.5	3,447.1
1995[2]	1.4	0.2	309.4	1,826.4	1,920.0	686.6	780.2	834.0	59.6	2,360.4

[1]Values for 1994 are prorations of total landings in CFDETS94 based on the average, by market category, during the period 1989-1993, of landings from northern and southern assessment area (value for gutted is based on ratio of known statistical areas). [2]Values for 1995 are landings from WORAW95ALL [northern = (ME, NH and part of MA); southern = (part of MA and RI-VA)]. MA landings were partitioned by averages, by market category, from CFDETS89 - 93 known statistical areas.

Table A7. Stratified mean weight (kg), number, and length (cm) per tow for goosefish from NEFSC offshore autumn research vessel bottom trawl surveys in the Gulf of Maine - Northern Georges Bank region (strata 20-30, 34-40); confidence limits for both the raw index and the indices smoothed using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of tows completed in each year.

	Biomass						Abundance									
	Raw index			Smoothed			Raw index			Smoothed			Length			Number
Year	Mean	L95%CL	U95%CL	Mean	L95%CL	U95%CL	Mean	L95%CL	U95%CL	Mean	L95%CL	U95%CL	Min	Mean	Max	of tows
1963	3.76	2.16	5.35	2.84	-	-	0.80	0.51	1.09	0.57	-	-	11	58.3	111	90
1964	1.71	0.90	2.53	2.36	-	-	0.39	0.22	0.56	0.45	-	-	21	59.4	102	87
1965	2.51	1.35	3.67	2.42	-	-	0.35	0.23	0.46	0.40	-	-	28	71.6	110	88
1966	3.27	2.10	4.43	2.43	1.64	3.60	0.49	0.33	0.65	0.38	0.26	0.53	37	73.1	96	86
1967	1.28	0.44	2.13	2.00	1.35	2.96	0.19	0.09	0.29	0.30	0.21	0.42	48	70.3	92	82
1968	2.04	0.52	3.55	2.22	1.50	3.29	0.29	0.12	0.46	0.32	0.23	0.46	11	71.4	106	86
1969	3.70	1.78	5.63	2.62	1.77	3.88	0.42	0.28	0.56	0.37	0.26	0.53	13	78.8	110	88
1970	2.24	0.95	3.53	2.44	1.65	3.62	0.40	0.22	0.57	0.39	0.28	0.56	22	67.2	98	92
1971	2.91	1.44	4.39	2.41	1.63	3.58	0.49	0.13	0.67	0.41	0.29	0.58	15	67.0	101	94
1972	1.40	0.65	2.16	2.10	1.42	3.12	0.32	0.20	0.44	0.38	0.27	0.55	21	56.9	99	94
1973	3.11	1.78	4.45	2.41	1.63	3.57	0.51	0.32	0.71	0.40	0.28	0.57	16	65.2	112	92
1974	2.06	1.11	3.01	2.32	1.57	3.44	0.31	0.19	0.44	0.37	0.26	0.52	13	64.9	111	97
1975	1.71	1.00	2.42	2.43	1.64	3.60	0.30	0.18	0.42	0.37	0.26	0.52	11	62.9	102	106
1976	3.39	1.56	5.22	3.23	2.18	4.78	0.42	0.24	0.60	0.43	0.30	0.61	29	72.1	121	87
1977	5.57	3.49	7.65	4.14	2.79	6.13	0.63	0.46	0.79	0.50	0.35	0.71	21	71.1	119	126
1978	5.10	3.49	6.71	4.35	2.94	6.45	0.58	0.43	0.73	0.51	0.36	0.73	10	67.6	116	201
1979	5.13	3.57	6.70	4.11	2.78	6.09	0.47	0.36	0.58	0.48	0.34	0.68	15	73.5	115	211
1980	4.46	2.23	6.68	3.35	2.26	4.96	0.53	0.37	0.70	0.45	0.31	0.64	6	63.9	111	97
1981	1.98	1.18	2.79	2.25	1.52	3.34	0.41	0.29	0.52	0.37	0.26	0.53	9	57.5	101	93
1982	0.94	0.38	1.49	1.65	1.11	2.45	0.14	0.07	0.21	0.29	0.21	0.41	29	68.9	100	95
1983	1.62	0.93	2.31	1.77	1.19	2.62	0.47	0.28	0.66	0.37	0.26	0.53	13	53.0	96	82
1984	3.01	1.41	4.61	2.00	1.35	2.97	0.48	0.35	0.61	0.41	0.29	0.58	11	62.7	106	88
1985	1.44	0.42	2.46	1.73	1.17	2.56	0.37	0.19	0.55	0.41	0.29	0.58	12	53.1	102	88
1986	2.35	1.10	3.61	1.69	1.14	2.50	0.60	0.38	0.83	0.43	0.30	0.61	19	53.8	100	90
1987	0.87	0.26	1.49	1.31	0.89	1.95	0.26	0.12	0.41	0.36	0.25	0.51	15	52.2	96	87
1988	1.52	0.48	2.57	1.35	0.91	2.00	0.31	0.13	0.50	0.38	0.27	0.54	11	57.1	93	89
1989	1.38	0.48	2.29	1.29	0.87	1.90	0.43	0.27	0.59	0.45	0.32	0.64	9	40.8	96	87
1990	1.00	0.44	1.56	1.17	0.79	1.73	0.59	0.38	0.80	0.55	0.39	0.79	9	32.3	89	89
1991	1.24	0.57	1.90	1.17	0.79	1.74	0.58	0.38	0.77	0.65	0.46	0.93	9	38.3	95	88
1992	1.10	0.56	1.65	1.13	0.76	1.68	0.98	0.64	1.32	0.83	0.58	1.18	9	32.5	86	86
1993	1.04	0.34	1.75	1.12	0.75	1.66	0.99	0.69	1.28	0.95	0.67	1.36	6	27.1	94	86
1994	0.97	0.38	1.57	1.16	0.77	1.75	1.35	0.97	1.73	1.06	0.73	1.53	9	24.9	98	87
1995	1.71	0.66	2.76	1.36	0.84	2.18	0.92	0.69	1.16	1.00	0.66	1.53	10	39.6	91	93

Table A8. Stratified mean weight (kg), number, and length (cm) per tow for goosefish from NEFSC offshore spring research vessel bottom trawl surveys in the Gulf of Maine - Northern Georges Bank region (strata 20-30, 34-40); confidence limits for both the raw index and the indices smoothed using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of tows completed in each year.

	Biomass						Abundance									
	Raw index			Smoothed			Raw index			Smoothed			Length			Number of tows
Year	Mean	L95%CL	U95%CL	Mean	L95%CL	U95%CL	Mean	L95%CL	U95%CL	Mean	L95%CL	U95%CL	Min	Mean	Max	
1968	0.97	0.26	1.69	1.19	-	-	0.18	0.07	0.28	0.20	-	-	50	70.4	90	86
1969	1.31	0.14	2.48	1.36	-	-	0.19	0.05	0.33	0.22	-	-	33	71.5	100	87
1970	1.97	0.71	3.22	1.59	-	-	0.34	0.22	0.47	0.27	-	-	30	65.4	99	90
1971	1.02	0.41	1.63	1.61	1.07	2.43	0.16	0.07	0.25	0.27	0.18	0.40	45	72.6	100	96
1972	4.64	3.02	6.27	2.23	1.48	3.36	0.64	0.45	0.83	0.39	0.26	0.59	13	72.7	105	96
1973	1.91	0.96	2.86	1.88	1.25	2.84	0.43	0.18	0.69	0.41	0.27	0.61	17	65.7	106	87
1974	1.48	0.86	2.09	1.57	1.04	2.37	0.44	0.32	0.56	0.41	0.27	0.61	20	58.3	111	83
1975	0.93	0.59	1.28	1.37	0.91	2.07	0.34	0.23	0.45	0.38	0.26	0.57	16	54.0	109	87
1976	2.83	1.69	3.96	1.55	1.03	2.34	0.67	0.47	0.88	0.39	0.26	0.59	14	61.5	106	99
1977	1.01	0.56	1.46	1.17	0.78	1.77	0.26	0.16	0.36	0.28	0.19	0.42	10	63.4	106	107
1978	0.63	0.34	0.91	0.98	0.65	1.48	0.14	0.10	0.19	0.22	0.14	0.32	15	65.5	92	113
1979	0.89	0.27	1.51	1.10	0.73	1.66	0.14	0.10	0.19	0.22	0.15	0.33	12	62.5	118	139
1980	1.62	0.79	2.46	1.43	0.95	2.16	0.38	0.27	0.49	0.29	0.20	0.44	17	53.3	107	85
1981	1.74	0.91	2.58	1.72	1.14	2.59	0.38	0.28	0.47	0.33	0.22	0.50	11	57.7	120	87
1982	3.02	1.27	4.76	2.03	1.35	3.06	0.35	0.16	0.54	0.35	0.23	0.52	25	68.8	108	92
1983	1.59	0.53	2.64	1.84	1.22	2.77	0.42	0.19	0.65	0.37	0.24	0.55	12	49.9	112	90
1984	1.70	0.60	2.80	1.84	1.22	2.78	0.33	0.18	0.47	0.35	0.23	0.52	17	60.8	100	86
1985	2.11	1.09	3.13	1.95	1.29	2.94	0.35	0.20	0.49	0.35	0.23	0.52	13	66.9	108	81
1986	2.16	0.95	3.38	1.96	1.30	2.95	0.34	0.20	0.48	0.35	0.23	0.52	11	65.4	121	90
1987	1.73	0.73	2.73	1.83	1.22	2.76	0.24	0.14	0.35	0.35	0.24	0.53	16	64.2	100	83
1988	2.11	0.91	3.32	1.79	1.19	2.70	0.61	0.40	0.82	0.45	0.30	0.68	10	49.8	110	90
1989	1.63	0.61	2.65	1.56	1.04	2.36	0.62	0.32	0.93	0.48	0.32	0.72	10	43.2	94	85
1990	1.00	0.37	1.64	1.33	0.88	2.00	0.28	0.16	0.41	0.43	0.29	0.64	15	49.1	107	89
1991	1.83	0.48	3.18	1.36	0.90	2.05	0.59	0.37	0.81	0.50	0.34	0.75	12	42.3	100	86
1992	0.89	-0.22	2.00	1.15	0.76	1.73	0.49	0.16	0.83	0.53	0.35	0.79	16	40.6	101	83
1993	1.16	0.69	1.63	1.15	0.76	1.73	0.68	0.48	0.89	0.59	0.39	0.88	10	41.0	90	87
1994	0.95	0.38	1.52	1.13	0.75	1.72	0.45	0.28	0.63	0.59	0.39	0.89	10	41.0	89	88
1995	1.71	0.79	2.64	1.27	0.83	1.94	0.98	0.66	1.31	0.71	0.47	1.09	15	39.9	97	88
1996	1.01	0.45	1.56	1.16	0.71	1.90	0.67	0.34	0.99	0.70	0.43	1.13	15	43.0	70	82

Table A9. Stratified mean weight (kg), number, and length (cm) per tow for goosefish from NEFSC summer research vessel bottom trawl surveys in the Gulf of Maine region; confidence limits for indices; minimum and maximum lengths; number of tows completed.

Year	Biomass raw index			Abundance raw index			Length			Number of tows
	Mean	L95%CL	U95%CL	Mean	L95%CL	U95%CL	Min	Mean	Max	
1991	2.15	-0.55	4.84	1.87	-0.10	3.83	14	35.9	74	51
1992	2.50	-0.80	5.80	1.20	0.09	2.31	9	39.5	88	62
1993	1.92	1.23	2.60	1.30	0.97	1.64	9	36.3	101	93
1994	1.28	0.66	1.90	1.40	0.77	2.03	13	30.2	89	35
1995	1.68	0.91	2.44	1.29	0.92	1.66	15	36.2	111	39

Table A10. Stratified mean number and length (cm) per tow for goosefish from NEFSC summer scallop surveys in the Northern Georges Bank region; confidence limits for both the raw index and the indices smoothed using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of tows completed in each year.

Year	Biomass raw index			Abundance raw index			Length			Number of tows
	Mean	L95%CL	U95%CL	Mean	L95%CL	U95%CL	Min	Mean	Max	
1984	0.54	0.35	0.73	0.62	-	-	34	62.9	115	86
1985	0.84	0.53	1.16	0.68	-	-	25	54.1	98	85
1986	0.72	0.43	1.02	0.65	-	-	18	57.0	97	98
1987	0.38	0.23	0.54	0.58	0.40	0.84	14	51.2	101	96
1988	0.54	0.36	0.71	0.68	0.47	0.99	23	56.1	96	98
1989	1.57	0.64	2.49	0.95	0.66	1.37	15	47.4	96	60
1990	0.77	0.43	1.10	0.94	0.65	1.36	12	47.1	81	84
1991	1.03	0.68	1.39	1.06	0.73	1.54	8	33.9	90	99
1992	1.34	1.03	1.66	1.23	0.85	1.77	8	37.9	91	96
1993	1.28	0.83	1.73	1.33	0.92	1.93	9	25.9	79	87
1994	1.47	1.03	1.92	1.49	1.03	2.16	13	34.3	93	99
1995	2.19	1.47	2.91	1.68	1.14	2.47	11	38.2	86	98
1996	1.45	0.94	1.96	1.58	1.02	2.47	12	41.6	80	94

Table A11. Stratified mean weight (kg), number, and length (cm) per tow for goosefish from ASMFC summer shrimp surveys in the Gulf of Maine region; confidence limits for indices; minimum and maximum lengths; number of tows completed.

Year	Biomass raw index			Abundance raw index			Length			Number of tows
	Mean	L95%CL	U95%CL	Mean	L95%CL	U95%CL	Min	Mean	Max	
1986	2.11	1.16	3.06	0.80	0.31	1.29	14	46.6	85	54
1987	7.25	2.53	11.98	2.08	1.27	2.90	10	39.8	110	57
1988	-	-	-	-	-	-	-	-	-	43
1989	0.74	0.29	1.19	0.88	0.20	1.56	13	30.0	72	49
1990	1.79	0.65	2.93	0.84	0.40	1.29	9	41.4	97	48
1991	1.71	1.01	2.42	2.73	1.98	3.48	9	26.4	96	55
1992	3.26	1.88	4.65	3.30	2.54	4.06	5	30.7	97	55
1993	3.13	1.42	4.84	4.10	1.85	6.35	7	26.6	102	53
1994	1.57	0.84	2.31	3.18	2.25	4.12	5	24.4	95	47
1995	1.64	0.73	2.54	2.09	1.22	2.96	11	31.2	76	35
1996	3.63	1.58	5.68	3.39	2.24	4.46	13	33.9	90	34

Table A12. Stratified mean weight (kg), number, and length (cm) per tow for goosefish from NEFSC offshore autumn research vessel bottom trawl surveys in the Southern Georges Bank - Mid-Atlantic region (strata 1-19, 61-76); confidence limits for both the raw index and the indices smoothed using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of tows completed in each year.

	Biomass						Abundance									
	Raw index			Smoothed			Raw index			Smoothed			Length			Number
Year	Mean	L95%CL	U95%CL	Mean	L95%CL	U95%CL	Mean	L95%CL	U95%CL	Mean	L95%CL	U95%CL	Min	Mean	Max	of tows
1963	3.72	1.79	5.66	4.17	-	-	1.26	0.75	1.77	1.31	-	-	7	50.4	97	73
1964	5.49	3.39	7.58	4.50	-	-	1.64	0.91	2.37	1.34	-	-	14	52.0	101	83
1965	5.16	2.73	7.59	4.25	-	-	1.15	0.78	1.52	1.20	-	-	10	56.3	104	85
1966	6.99	4.94	9.04	3.52	2.00	6.18	1.93	1.36	2.49	1.11	0.62	2.00	7	49.6	98	87
1967	1.12	0.59	1.66	1.84	1.05	3.23	0.54	0.34	0.74	0.71	0.40	1.27	14	40.6	100	163
1968	0.89	0.45	1.34	1.34	0.76	2.35	0.41	0.21	0.60	0.55	0.31	0.98	12	46.8	86	164
1969	1.14	0.48	1.79	1.29	0.73	2.26	0.50	0.28	0.71	0.51	0.28	0.91	10	45.4	96	163
1970	1.36	0.51	2.20	1.34	0.76	2.35	0.35	0.24	0.47	0.48	0.27	0.87	4	53.3	104	161
1971	0.79	0.20	1.38	1.38	0.79	2.42	0.28	0.15	0.41	0.57	0.32	1.02	5	42.3	98	168
1972	4.92	3.30	6.54	2.07	1.18	3.63	4.11	1.28	6.94	1.07	0.60	1.91	12	31.8	99	161
1973	1.99	0.99	2.98	1.73	0.98	3.04	1.18	0.86	1.49	0.81	0.45	1.46	13	37.7	93	154
1974	0.71	0.32	1.10	1.31	0.75	2.31	0.22	0.12	0.32	0.48	0.27	0.87	14	52.9	101	153
1975	2.04	1.33	2.76	1.51	0.86	2.65	0.65	0.43	0.87	0.49	0.27	0.87	8	46.3	105	163
1976	1.08	0.54	1.63	1.42	0.81	2.49	0.31	0.19	0.44	0.40	0.22	0.72	11	50.7	95	165
1977	1.87	1.19	2.55	1.60	0.91	2.82	0.37	0.27	0.48	0.39	0.22	0.71	5	53.1	106	172
1978	1.39	0.88	1.91	1.63	0.93	2.87	0.26	0.18	0.34	0.40	0.22	0.72	13	56.5	101	219
1979	2.28	1.28	3.27	1.85	1.05	3.25	0.69	0.48	0.91	0.55	0.31	0.99	7	40.5	109	205
1980	1.87	1.17	2.57	1.82	1.03	3.19	0.73	0.43	1.03	0.65	0.36	1.17	3	41.6	104	159
1981	2.86	0.88	4.83	1.75	1.00	3.08	0.97	0.58	1.35	0.71	0.40	1.28	6	40.7	99	146
1982	0.65	0.35	0.94	1.22	0.69	2.14	0.61	0.37	0.85	0.64	0.36	1.14	13	32.5	73	143
1983	2.15	0.69	3.61	1.29	0.74	2.27	0.78	0.47	1.08	0.59	0.33	1.06	7	44.4	100	146
1984	0.74	0.15	1.33	0.98	0.56	1.72	0.31	0.11	0.51	0.45	0.25	0.81	5	45.7	93	146
1985	1.32	0.75	1.88	0.89	0.51	1.56	0.52	0.36	0.69	0.44	0.25	0.79	17	42.0	96	145
1986	0.55	0.24	0.87	0.62	0.35	1.09	0.33	0.17	0.48	0.39	0.22	0.70	7	37.6	78	146
1987	0.27	0.12	0.43	0.47	0.27	0.82	0.48	0.31	0.66	0.39	0.21	0.69	12	25.0	61	132
1988	0.55	0.21	0.90	0.51	0.29	0.90	0.23	0.10	0.36	0.33	0.18	0.59	19	45.1	91	129
1989	0.63	0.28	0.97	0.54	0.30	0.94	0.38	0.18	0.59	0.36	0.20	0.64	7	38.0	77	128
1990	0.43	0.02	0.83	0.50	0.29	0.88	0.29	0.11	0.47	0.37	0.21	0.66	9	33.1	81	136
1991	0.78	0.21	1.36	0.52	0.30	0.91	0.69	0.25	1.14	0.44	0.25	0.79	14	30.8	81	131
1992	0.31	0.17	0.45	0.41	0.23	0.72	0.34	0.22	0.46	0.39	0.22	0.71	8	32.2	74	129
1993	0.29	0.06	0.53	0.39	0.22	0.69	0.29	0.14	0.45	0.39	0.22	0.70	10	30.4	68	130
1994	0.61	0.18	1.05	0.45	0.25	0.81	0.60	0.34	0.85	0.47	0.25	0.86	8	29.2	83	135
1995	0.39	0.16	0.61	0.43	0.22	0.84	0.49	0.26	0.73	0.48	0.24	0.96	11	29.4	66	129

Table A13. Stratified mean weight (kg), number, and length (cm) per tow for goosefish from NEFSC offshore spring research vessel bottom trawl surveys in the Southern Georges Bank - Mid-Atlantic region (strata 1-19, 61-76); confidence limits for both the raw index and the indices smoothed using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of tows completed in each year.

	Biomass						Abundance									
	Raw index			Smoothed			Raw index			Smoothed			Length			Number
Year	Mean	L95%CL	U95%CL	Mean	L95%CL	U95%CL	Mean	L95%CL	U95%CL	Mean	L95%CL	U95%CL	Min	Mean	Max	of tows
1968	1.14	0.55	1.73	1.07	-	-	0.21	0.13	0.30	0.21	-	-	21	62.5	95	150
1969	0.94	0.43	1.45	1.02	-	-	0.22	0.14	0.31	0.22	-	-	7	54.3	111	155
1970	1.00	0.46	1.55	1.03	-	-	0.17	0.10	0.25	0.22	-	-	22	63.9	108	166
1971	0.76	0.31	1.21	1.06	0.69	1.63	0.20	0.10	0.30	0.26	0.17	0.41	13	53.3	115	160
1972	1.88	1.16	2.60	1.36	0.89	2.09	0.37	0.27	0.47	0.37	0.24	0.58	14	59.1	123	165
1973	1.86	1.49	2.22	1.41	0.92	2.17	1.05	0.85	1.25	0.53	0.34	0.84	11	41.1	110	187
1974	1.13	0.73	1.53	1.22	0.79	1.87	0.49	0.37	0.60	0.49	0.31	0.76	14	49.1	117	132
1975	0.94	0.56	1.31	1.10	0.72	1.69	0.45	0.33	0.57	0.44	0.28	0.69	10	47.6	107	134
1976	1.21	0.83	1.59	1.11	0.72	1.70	0.40	0.31	0.50	0.40	0.25	0.62	13	51.5	110	162
1977	1.23	0.77	1.68	1.05	0.69	1.62	0.30	0.23	0.37	0.35	0.23	0.56	16	57.0	116	161
1978	0.74	0.51	0.96	0.91	0.59	1.39	0.33	0.27	0.41	0.35	0.23	0.55	11	45.9	104	161
1979	0.73	0.44	1.03	0.90	0.58	1.38	0.28	0.16	0.40	0.36	0.23	0.57	10	44.4	124	194
1980	0.80	0.49	1.10	1.01	0.66	1.56	0.45	0.35	0.55	0.45	0.29	0.70	18	40.8	106	204
1981	1.82	1.15	2.49	1.35	0.88	2.07	0.78	0.54	1.03	0.54	0.35	0.85	12	44.6	113	141
1982	2.80	1.58	4.02	1.46	0.95	2.25	0.94	0.66	1.23	0.52	0.33	0.81	11	42.4	104	150
1983	0.95	0.42	1.49	1.03	0.67	1.58	0.27	0.18	0.37	0.33	0.21	0.51	24	51.8	112	147
1984	0.75	0.22	1.27	0.76	0.49	1.17	0.18	0.09	0.27	0.24	0.15	0.37	21	50.9	97	149
1985	0.33	0.09	0.57	0.57	0.37	0.87	0.16	0.07	0.25	0.21	0.13	0.33	22	42.3	90	147
1986	0.82	0.34	1.30	0.61	0.39	0.93	0.28	0.13	0.44	0.22	0.14	0.34	15	48.7	102	149
1987	0.50	-0.01	1.01	0.53	0.35	0.81	0.11	0.05	0.16	0.19	0.12	0.30	15	52.7	103	150
1988	0.43	0.26	0.59	0.48	0.32	0.75	0.44	0.28	0.60	0.25	0.16	0.40	17	34.0	82	132
1989	0.36	0.12	0.61	0.48	0.31	0.74	0.20	0.10	0.31	0.23	0.15	0.36	15	41.4	79	129
1990	1.00	0.43	1.58	0.57	0.37	0.88	0.21	0.10	0.31	0.22	0.14	0.35	16	56.5	93	128
1991	0.58	0.24	0.93	0.47	0.30	0.72	0.32	0.14	0.50	0.23	0.15	0.37	15	37.6	101	132
1992	0.21	0.07	0.35	0.33	0.21	0.51	0.18	0.09	0.27	0.20	0.13	0.31	14	35.0	85	128
1993	0.26	0.10	0.43	0.31	0.20	0.48	0.20	0.10	0.30	0.18	0.12	0.29	17	38.6	72	128
1994	0.32	0.12	0.53	0.34	0.22	0.52	0.11	0.06	0.17	0.16	0.10	0.25	13	43.8	93	131
1995	0.53	0.03	1.02	0.38	0.24	0.59	0.20	0.10	0.29	0.17	0.10	0.26	18	45.7	81	129
1996	0.28	0.11	0.46	0.33	0.20	0.56	0.14	0.07	0.20	0.15	0.09	0.27	9	43.7	81	143

Table A14. Stratified mean weight (kg), number, and length (cm) per tow for goosefish from NEFSC winter flatfish surveys in the Southern Georges Bank - Mid-Atlantic region; confidence limits for indices; minimum and maximum lengths; number of tows completed.

	Biomass raw index			Abundance raw index			Length			
Year	Mean	L95%CL	U95%CL	Mean	L95%CL	U95%CL	Min	Mean	Max	Number of tows
1992	5.39	3.52	7.28	5.18	3.67	6.69	11	36.0	95	110
1993	6.32	4.57	8.07	5.00	3.94	6.06	9	37.7	98	109
1994	2.79	1.96	3.62	2.53	1.86	3.21	8	35.1	78	82
1995	3.40	2.25	4.46	2.74	1.86	3.62	19	37.9	101	123
1996	5.70	4.68	6.72	3.78	3.04	4.52	10	41.1	100	123

Table A15. Stratified mean number and length (cm) per tow for goosefish from NEFSC summer scallop surveys in the Southern Georges Bank - Mid-Atlantic region; confidence limits for both the raw index and the indices smoothed using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of tows completed in each year.

	Biomass raw index			Abundance raw index			Length			
Year	Mean	L95%CL	U95%CL	Mean	L95%CL	U95%CL	Min	Mean	Max	Number of tows
1984	1.07	0.91	1.23	1.11	-	-	6	30.6	82	389
1985	1.07	0.92	1.23	1.14	-	-	7	32.8	113	404
1986	0.93	0.71	1.16	1.22	-	-	8	22.1	95	371
1987	2.42	1.93	2.91	1.56	1.16	2.10	8	18.7	90	433
1988	1.44	1.18	1.71	1.49	1.11	2.00	7	30.3	97	435
1989	1.24	1.08	1.41	1.46	1.09	1.96	6	33.7	101	352
1990	1.40	1.22	1.58	1.60	1.19	2.14	6	25.6	94	342
1991	2.22	1.94	2.50	1.90	1.42	2.56	7	21.0	94	323
1992	1.88	1.61	2.15	2.05	1.53	2.75	6	27.3	97	324
1993	2.64	2.39	2.89	2.33	1.74	3.13	8	22.4	79	325
1994	3.09	2.74	3.45	2.45	1.82	3.29	8	22.5	87	338
1995	2.09	1.83	2.36	2.19	1.61	2.98	7	30.0	92	338
1996	1.81	1.58	2.05	2.03	1.42	2.89	7	29.9	81	307

Table A16. Indices of spawning stock biomass of goosefish, 1967-1966, by region. Egg production index is a function of numbers at length, proportion mature at length, and fecundity at length, pooled over a 5-year interval. Proportion < L_{99} is proportion of egg production generated by fish smaller than the length at 99% maturity.

	North				South			
	Spring		Autumn		Spring		Autumn	
Year	Egg production index	Proportion < L99	Egg production index	Proportion < L99	Egg production index	Proportion < L99	Egg production index	Proportion < L99
1967	-	-	1,464,523	0.01	-	-	2,172,783	0.04
1968	-	-	1,231,407	0.01	-	-	1,852,725	0.04
1969	-	-	1,456,821	0.00	-	-	1,486,561	0.04
1970	-	-	1,412,398	0.00	-	-	1,116,257	0.04
1971	-	-	1,374,730	0.01	-	-	53,1770	0.05
1972	1,138,483	0.01	1,390,736	0.01	635,159	0.03	861,283	0.05
1973	1,304,964	0.01	1,543,281	0.01	718,217	0.04	939,559	0.05
1974	1,388,764	0.01	1,338,632	0.02	770,281	0.05	895,238	0.05
1975	1,271,690	0.01	1,266,063	0.02	758,000	0.07	933,751	0.06
1976	1,529,658	0.02	1,315,794	0.01	809,021	0.07	932,451	0.06
1977	1,133,515	0.02	1,691,116	0.01	746,140	0.07	655,547	0.06
1978	945,302	0.02	1,747,339	0.01	639,635	0.07	607,501	0.04
1979	831,745	0.02	1,978,672	0.01	578,822	0.06	676,012	0.04
1980	884,324	0.02	2,196,166	0.01	545,729	0.06	642,682	0.04
1981	706,589	0.02	1,996,152	0.01	586,585	0.09	705,817	0.06
1982	855,507	0.02	1,582,868	0.01	639,911	0.10	577,754	0.09
1983	937,170	0.02	1,284,651	0.02	639,653	0.11	614,255	0.11
1984	1,006,208	0.02	1,109,918	0.02	630,808	0.10	530,265	0.12
1985	1,058,050	0.02	872,527	0.02	581,077	0.11	487,451	0.13
1986	1,133,991	0.01	916,876	0.02	483,067	0.09	379,730	0.12
1987	1,013,200	0.01	907,336	0.03	334,326	0.07	356,257	0.11
1988	1,057,130	0.01	901,299	0.03	263,273	0.09	259,887	0.10
1989	1,012,957	0.03	721,412	0.05	201,365	0.16	232,685	0.17
1990	884,652	0.04	641,433	0.05	257,448	0.12	166,967	0.20
1991	742,170	0.05	506,975	0.07	219,859	0.13	169,658	0.22
1992	668,542	0.07	516,270	0.09	182,573	0.17	177,094	0.24
1993	561,642	0.11	457,185	0.11	173,583	0.18	135,735	0.35
1994	502,751	0.11	412,372	0.11	176,858	0.14	130,583	0.27
1995	548,231	0.11	477,596	0.13	139,608	0.17	126,840	0.30
1996	491,337	0.15	-	-	122,702	0.17	-	-

Table A17. Total instantaneous mortality rate (Z), goosefish, northern region, 1963-1995; approximate upper and lower 95% confidence intervals (minimum variance estimate); mean length, standard deviation and number of fish at length of capture or above.

	Total mortality (Z)			Length > 58		
Year	Median	L95%CL	U95%CL	Mean	SD(mean)	n
1963	0.23	0.17	0.37	79.93	2.31	17
1964	0.25	0.17	0.37	79.61	2.86	5
1965	0.20	0.13	0.28	82.99	2.32	7
1966	0.28	0.19	0.48	77.48	1.82	14
1967	0.42	0.26	0.83	72.75	3.72	2
1968	0.26	0.18	0.42	78.66	4.05	4
1969	0.19	0.13	0.28	83.13	2.45	11
1970	0.30	0.21	0.51	76.46	2.59	5
1971	0.28	0.19	0.45	77.58	2.27	10
1972	0.42	0.26	0.76	73.07	3.22	4
1973	0.17	0.12	0.26	84.77	3.45	8
1974	0.21	0.15	0.32	81.96	3.24	5
1975	0.26	0.17	0.42	78.74	2.57	5
1976	0.21	0.15	0.33	81.26	3.20	8
1977	0.25	0.17	0.39	79.12	2.00	27
1978	0.22	0.15	0.35	80.70	1.67	31
1979	0.19	0.13	0.28	83.22	1.66	30
1980	0.17	0.12	0.26	84.76	2.29	11
1981	0.30	0.21	0.51	76.58	2.49	5
1982	0.27	0.18	0.42	78.27	3.91	12
1983	0.51	0.30	1.17	70.69	3.43	15
1984	0.30	0.21	0.51	76.52	3.31	24
1985	0.32	0.21	0.55	75.78	4.61	13
1986	0.33	0.22	0.59	75.13	2.48	22
1987	0.37	0.25	0.69	73.79	5.45	8
1988	0.27	0.19	0.45	77.98	3.34	13
1989	0.18	0.13	0.27	83.86	4.64	8
1990	0.37	0.23	0.69	74.14	3.32	9
1991	0.48	0.30	1.03	71.21	3.75	12
1992	0.35	0.22	0.64	74.68	2.55	12
1993	0.23	0.16	0.35	80.30	4.15	6
1994	0.39	0.26	0.76	73.14	6.16	6
1995	0.28	0.19	0.48	77.39	3.60	10

Mean	
1970-1979	0.25
1991-1995	0.35

Table A18. Total instantaneous mortality rate (Z), goosefish, southern region, 1963-1995; approximate upper and lower 95% confidence intervals (minimum variance estimate); mean length, standard deviation and number of fish at length of capture or above.

	Total mortality (Z)			Length > 18		
Year	Median	L95%CL	U95%CL	Mean	SD(mean)	n
1965	0.21	0.17	0.27	58.84	3.62	37
1966	0.22	0.18	0.29	57.59	2.84	78
1967	0.46	0.35	0.71	41.25	4.36	14
1968	0.33	0.25	0.44	48.51	3.70	9
1969	0.33	0.26	0.44	48.42	3.20	19
1970	0.22	0.18	0.29	57.59	2.18	23
1971	0.26	0.21	0.33	53.67	2.91	13
1972	0.77	0.53	1.29	33.93	3.97	83
1973	0.46	0.35	0.71	41.09	2.66	47
1974	0.24	0.19	0.30	55.65	4.17	6
1975	0.33	0.25	0.44	48.50	3.14	26
1976	0.27	0.21	0.35	53.12	3.12	9
1977	0.23	0.18	0.29	56.90	3.19	20
1978	0.22	0.17	0.27	58.60	3.84	9
1979	0.44	0.32	0.61	43.18	3.13	31
1980	0.41	0.32	0.57	43.59	3.08	25
1981	0.46	0.33	0.65	42.11	2.77	36
1982	0.77	0.53	1.29	34.15	1.80	87
1983	0.35	0.27	0.46	47.15	2.50	76
1984	0.27	0.22	0.37	52.26	2.99	31
1985	0.41	0.32	0.61	43.28	2.40	85
1986	0.44	0.33	0.65	42.17	2.98	42
1987	1.14	0.65	2.58	29.79	2.35	40
1988	0.39	0.30	0.53	45.09	4.70	23
1989	0.41	0.32	0.57	43.63	2.18	31
1990	0.53	0.37	0.77	39.86	3.12	32
1991	0.77	0.49	1.29	34.16	2.37	59
1992	0.57	0.41	0.84	38.53	2.59	30
1993	0.65	0.44	1.02	36.57	2.74	22
1994	0.77	0.53	1.29	34.02	2.20	60
1995	0.77	0.49	1.29	34.17	2.14	47

Mean	
1970-1979	0.34
1991-1995	0.71

Table A19. Stratified mean catch per tow in weight (kg), 33rd percentile, three-year moving averages, medians, NEFSC offshore autumn research vessel bottom trawl survey in northern region (strata 20-30, 34-40); and southern region (strata 1-19, 61-76); means from delta distribution.

	Northern management/assessment area				Southern management/assessment area			
Year	Mean weight/ tow	33rd percentile 1963-1994 series	Three-year moving average	Median three-year moving average 1965-1981	Mean weight/ tow	33rd percentile 1963-1994 series	Three-year moving average	Median three-year moving average 1965-1981
1963	3.757	-	-	-	3.724	-	-	-
1964	1.712	-	-	-	5.486	-	-	-
1965	2.509	1.460	2.659	2.496	5.163	0.750	4.791	1.848
1966	3.266	-	2.496	-	6.986	-	5.878	-
1967	1.283	-	2.353	-	1.122	-	4.423	-
1968	2.036	-	2.195	-	0.895	-	3.001	-
1969	3.705	-	2.341	-	1.138	-	1.051	-
1970	2.237	-	2.659	-	1.357	-	1.130	-
1971	2.914	-	2.952	-	0.786	-	1.094	-
1972	1.404	-	2.185	-	4.918	-	2.354	-
1973	3.114	-	2.477	-	1.986	-	2.564	-
1974	2.063	-	2.193	-	0.710	-	2.538	-
1975	1.711	-	2.296	-	2.043	-	1.580	-
1976	3.387	-	2.387	-	1.084	-	1.279	-
1977	5.568	-	3.555	-	1.873	-	1.667	-
1978	5.101	-	4.685	-	1.395	-	1.451	-
1979	5.133	-	5.267	-	2.275	-	1.848	-
1980	4.458	-	4.897	-	1.868	-	1.846	-
1981	1.984	-	3.859	-	2.858	-	2.334	-
1982	0.936	-	2.459	-	0.646	-	1.791	-
1983	1.617	-	1.513	-	2.150	-	1.885	-
1984	3.010	-	1.855	-	0.740	-	1.179	-
1985	1.441	-	2.023	-	1.318	-	1.403	-
1986	2.353	-	2.268	-	0.552	-	0.870	-
1987	0.873	-	1.556	-	0.274	-	0.715	-
1988	1.525	-	1.584	-	0.554	-	0.460	-
1989	1.384	-	1.261	-	0.625	-	0.485	-
1990	1.001	-	1.303	-	0.426	-	0.535	-
1991	1.235	-	1.207	-	0.783	-	0.611	-
1992	1.102	-	1.113	-	0.312	-	0.507	-
1993	1.044	-	1.127	-	0.294	-	0.463	-
1994	0.973	-	1.040	-	0.611	-	0.406	-
1995	1.711	-	1.243	-	0.386	-	0.430	-

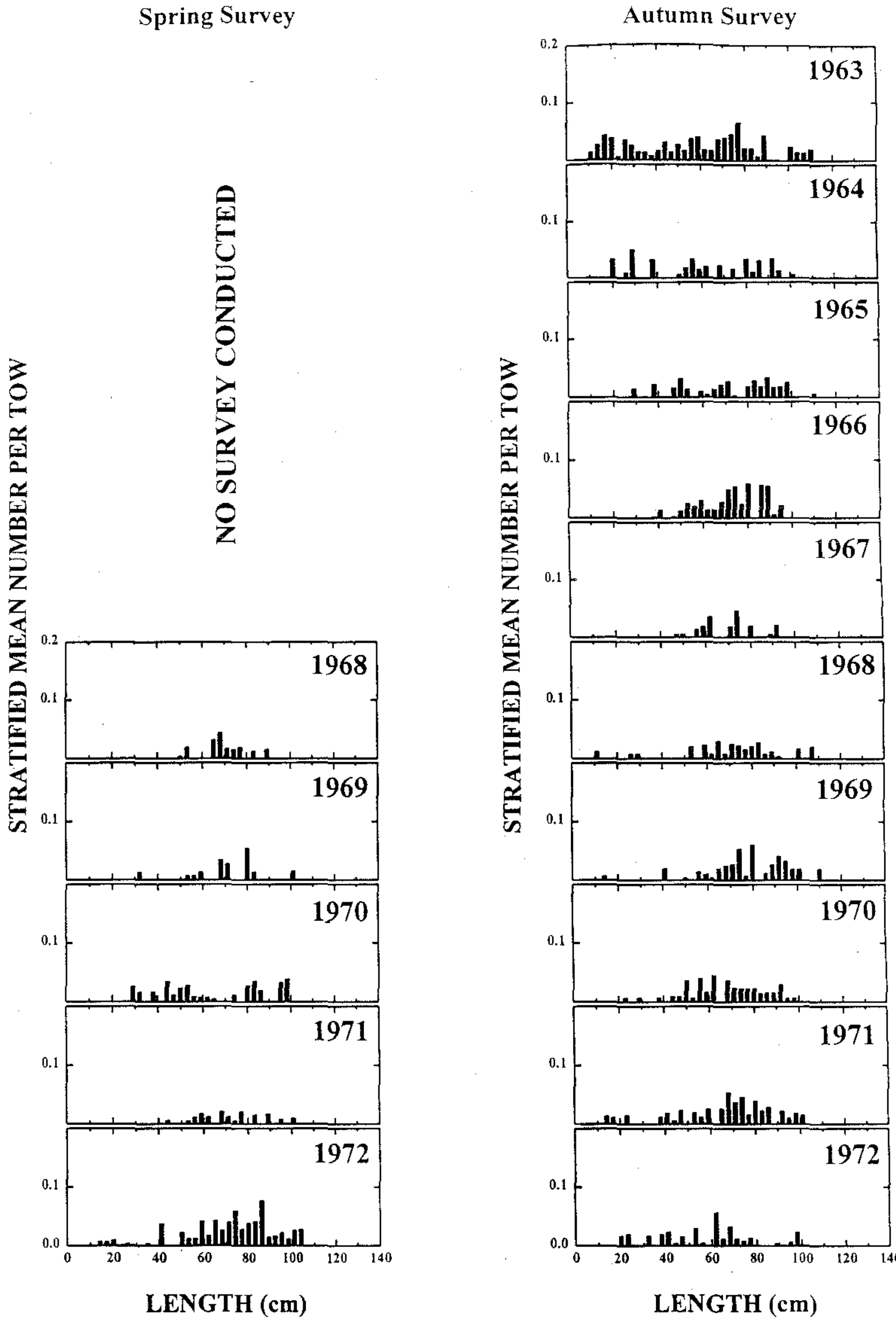


Figure A1. Goosefish length composition from the NEFSC spring bottom trawl (March-April), Gulf of Maine summer inshore bottom trawl (July-August), summer scallop dredge (July-August), and autumn bottom trawl (September-October) surveys and the ASMFC summer shrimp trawl survey (August) in the Gulf of Maine - Northern Georges Bank region, 1963-1996.

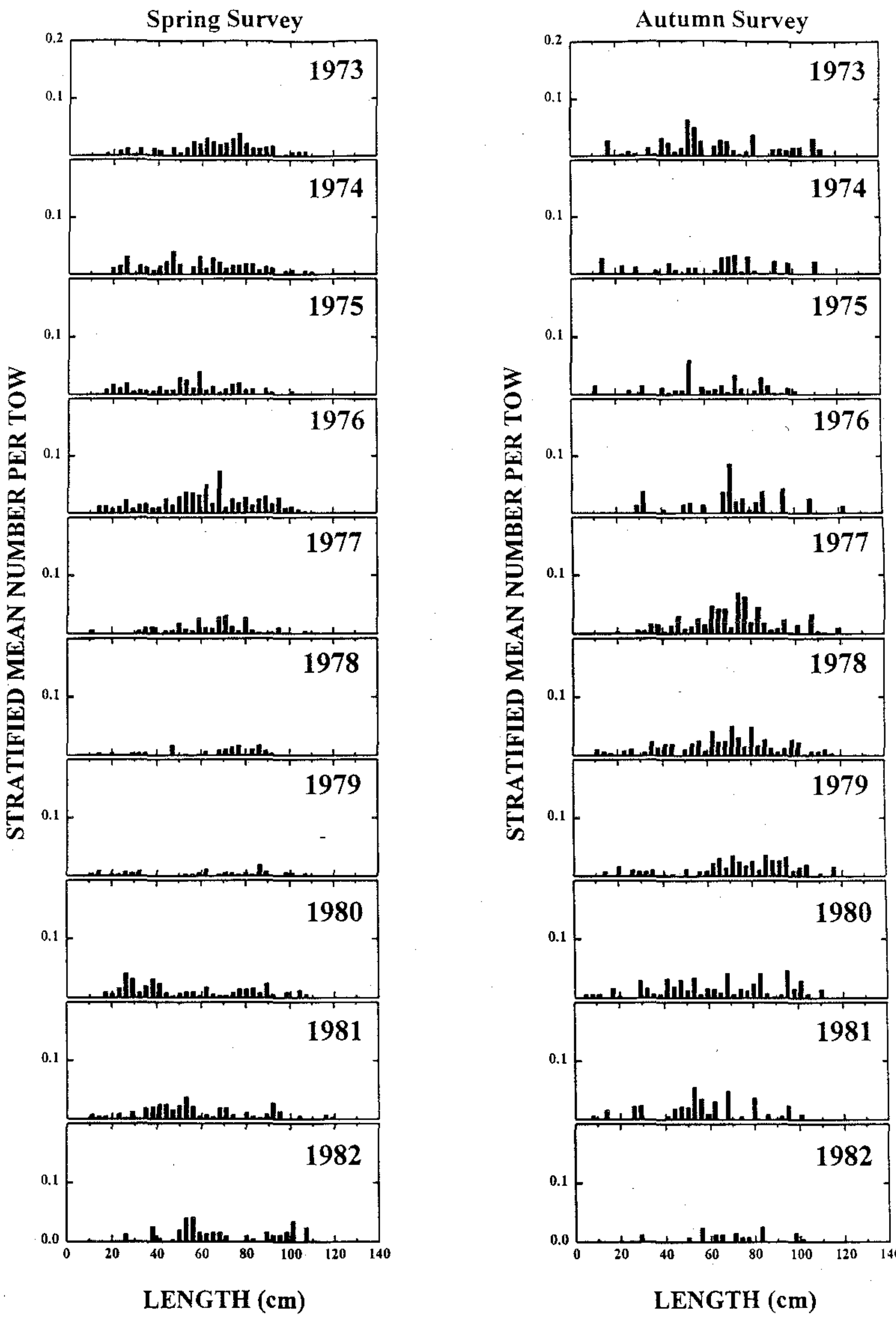
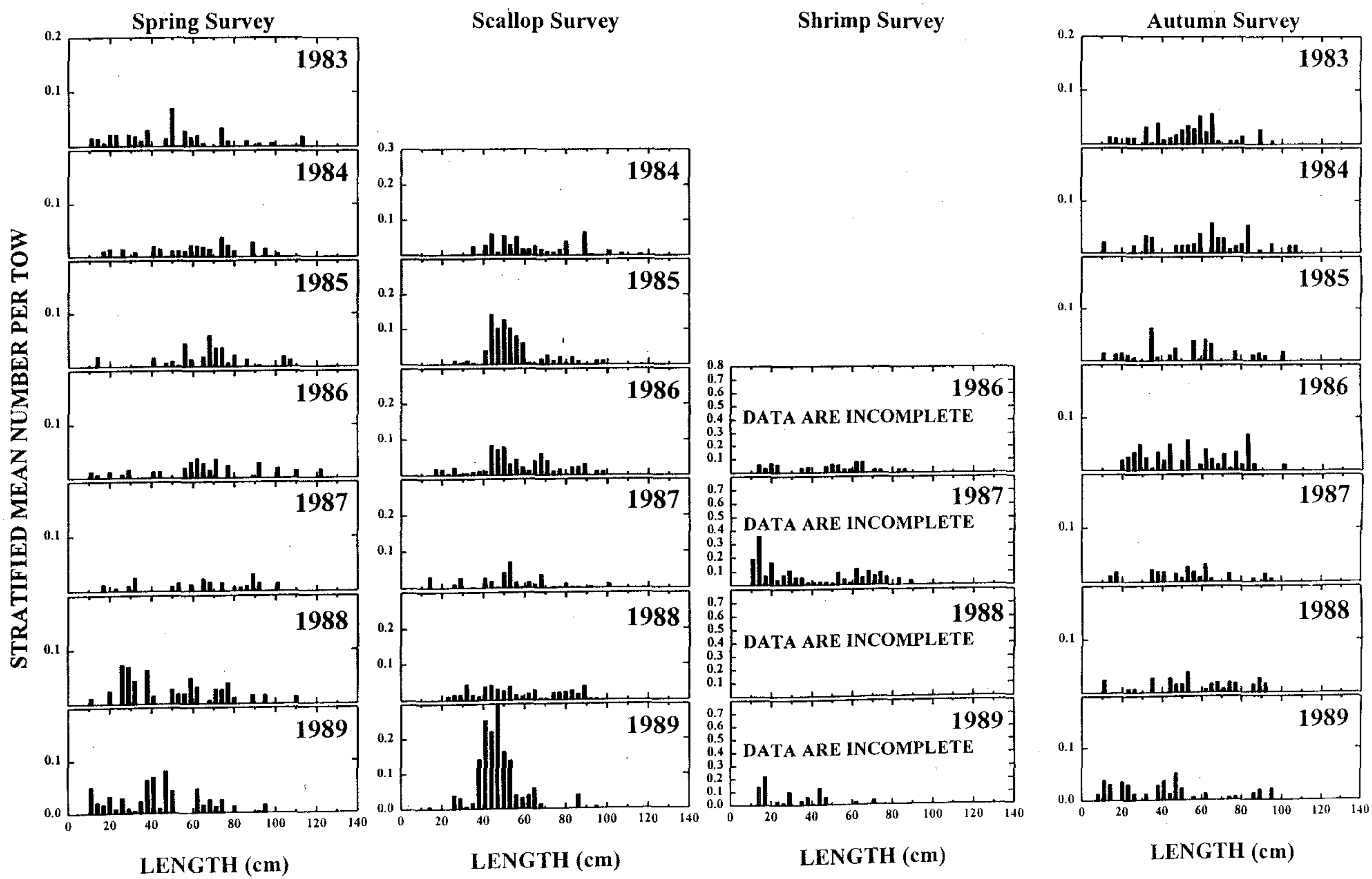


Figure A1. (Continued)



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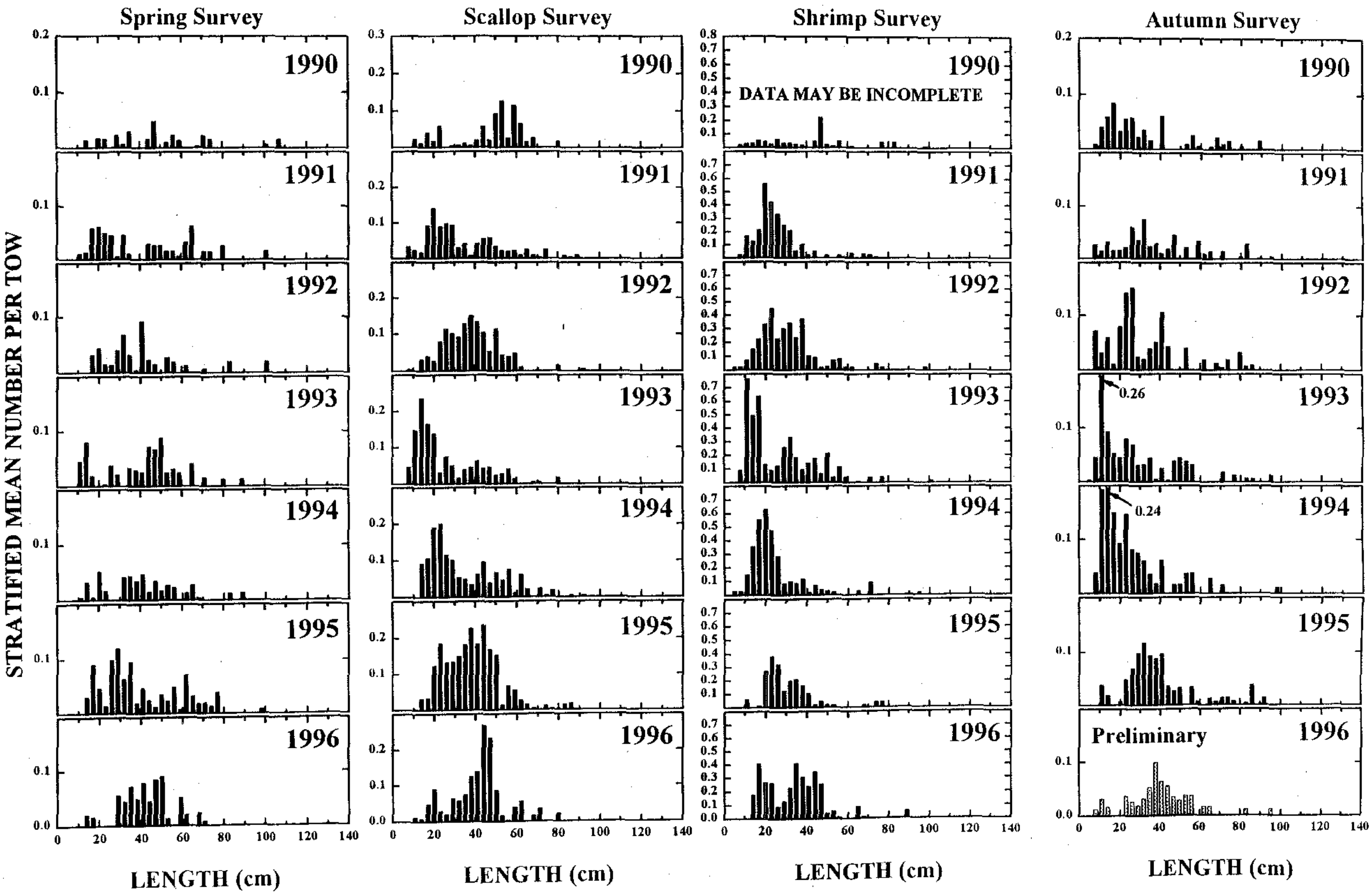

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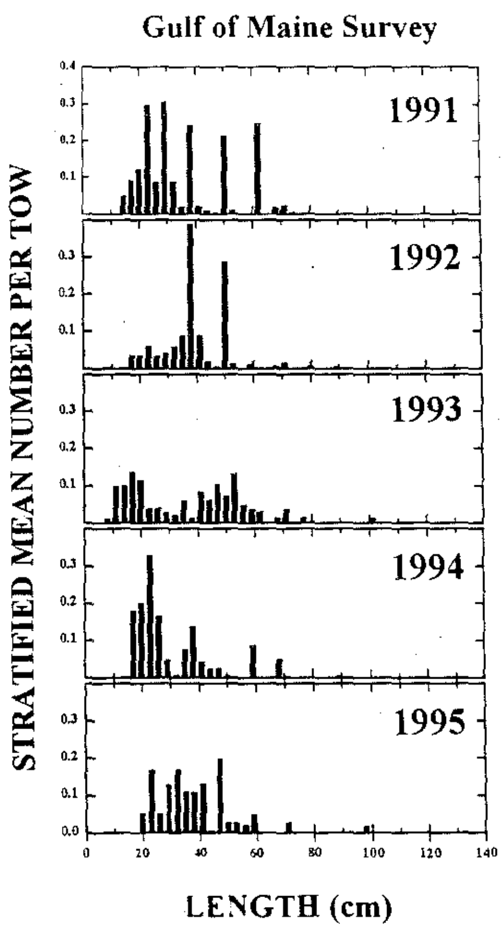

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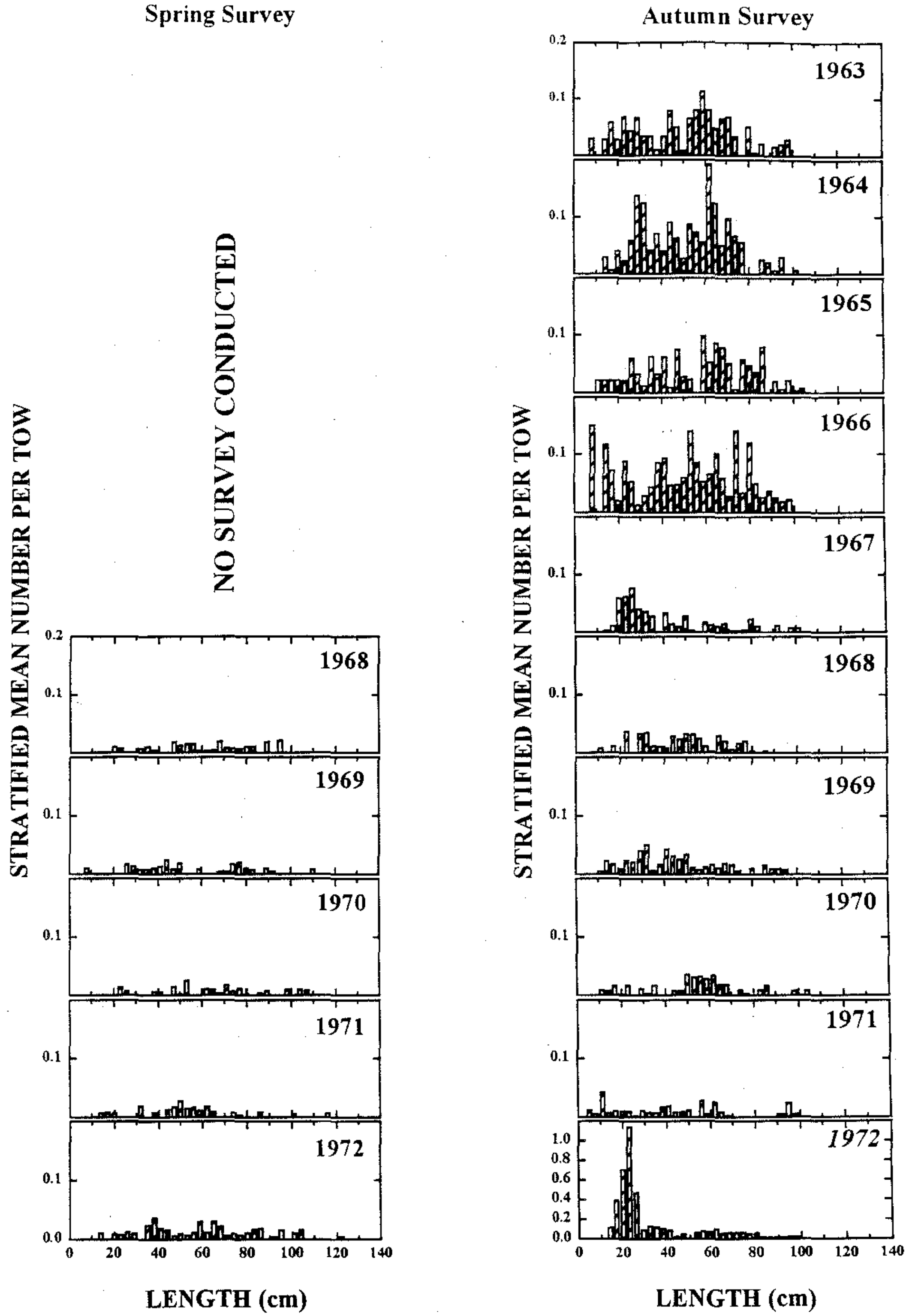
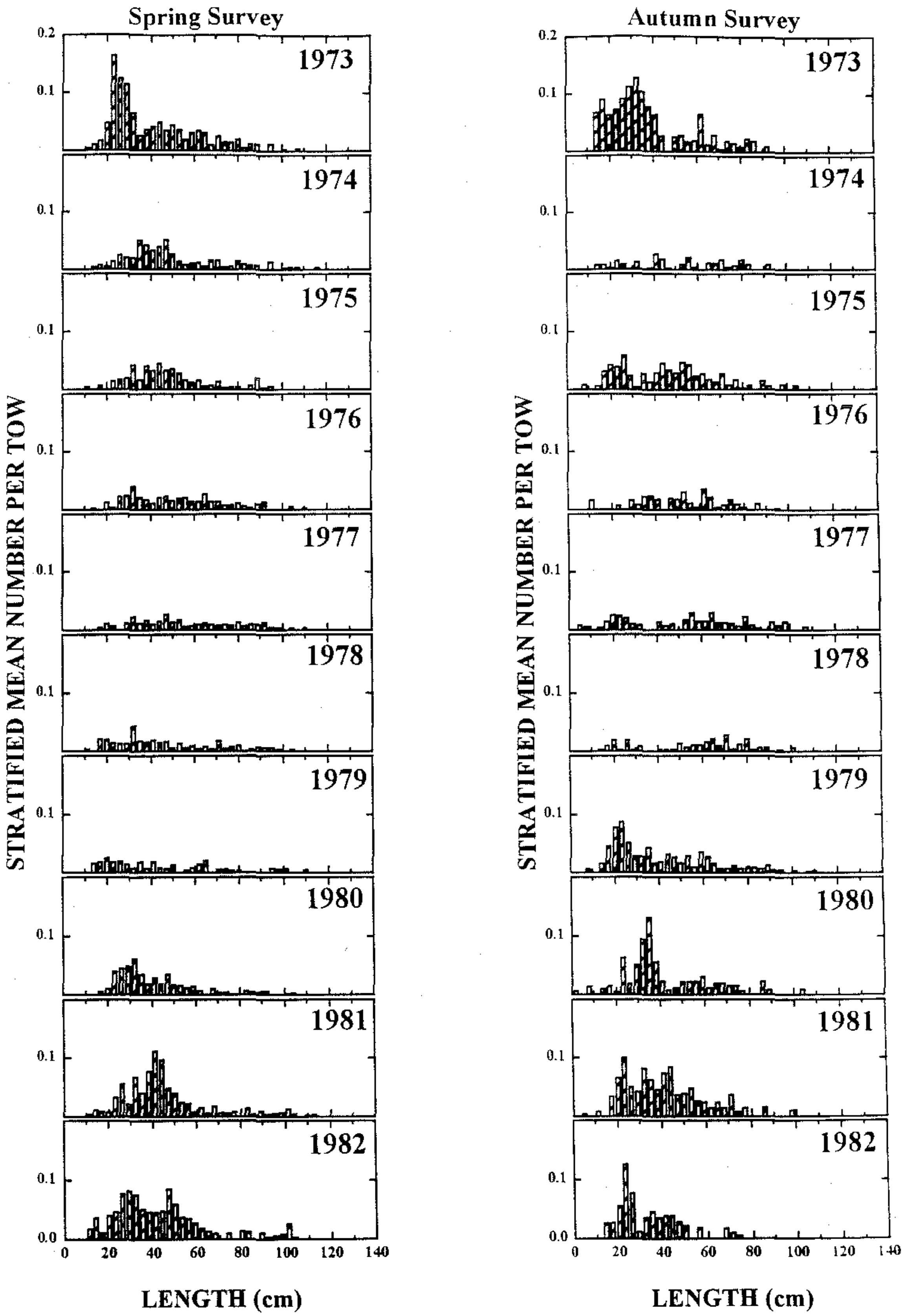


Figure A2. Goosefish length composition from the NEFSC spring bottom trawl (March-April), winter flatfish (February), summer scallop dredge (July-August), and autumn bottom trawl (September-October) surveys in the Southern Georges Bank - Mid-Atlantic region, 1963-1996.



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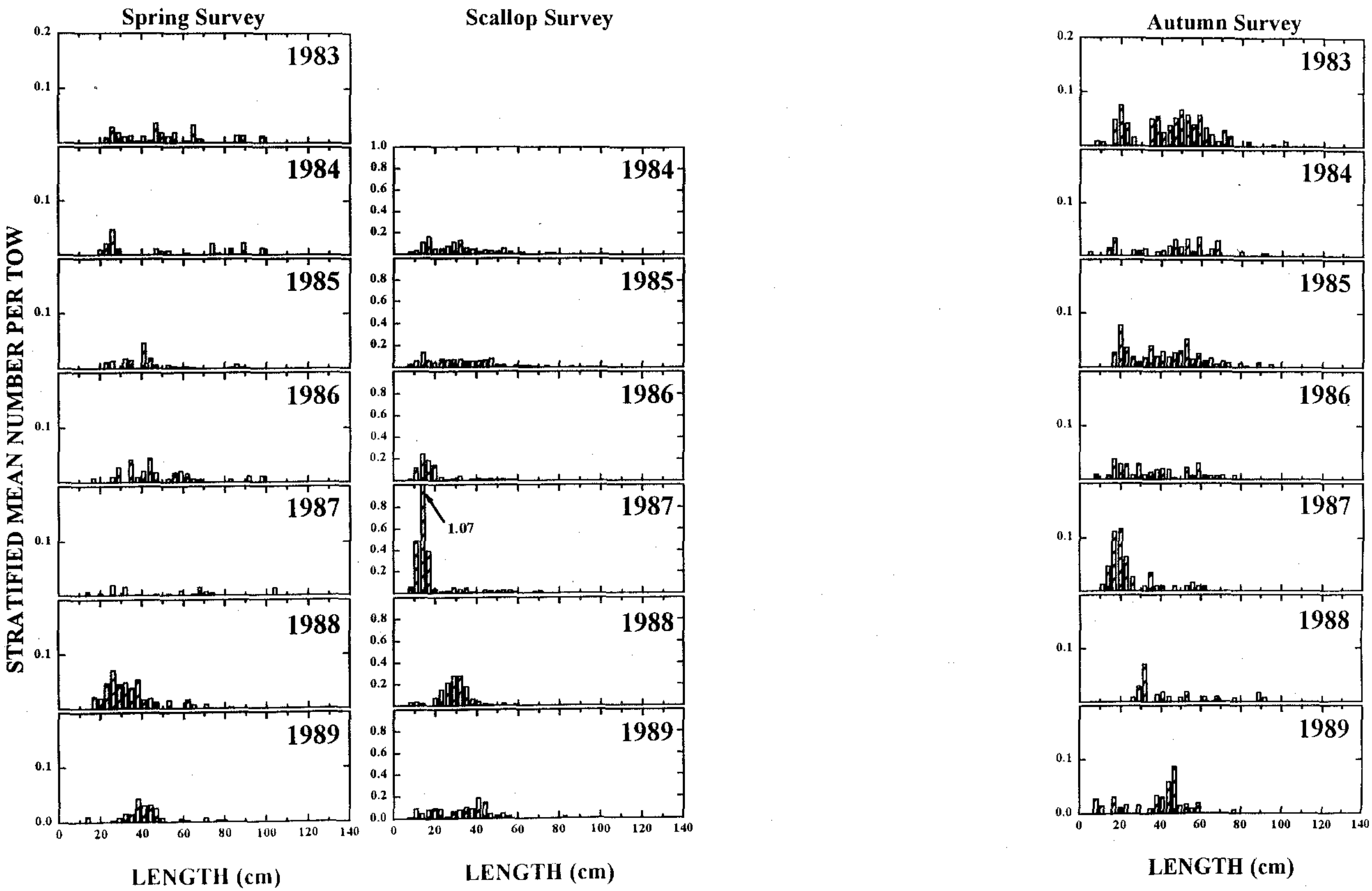

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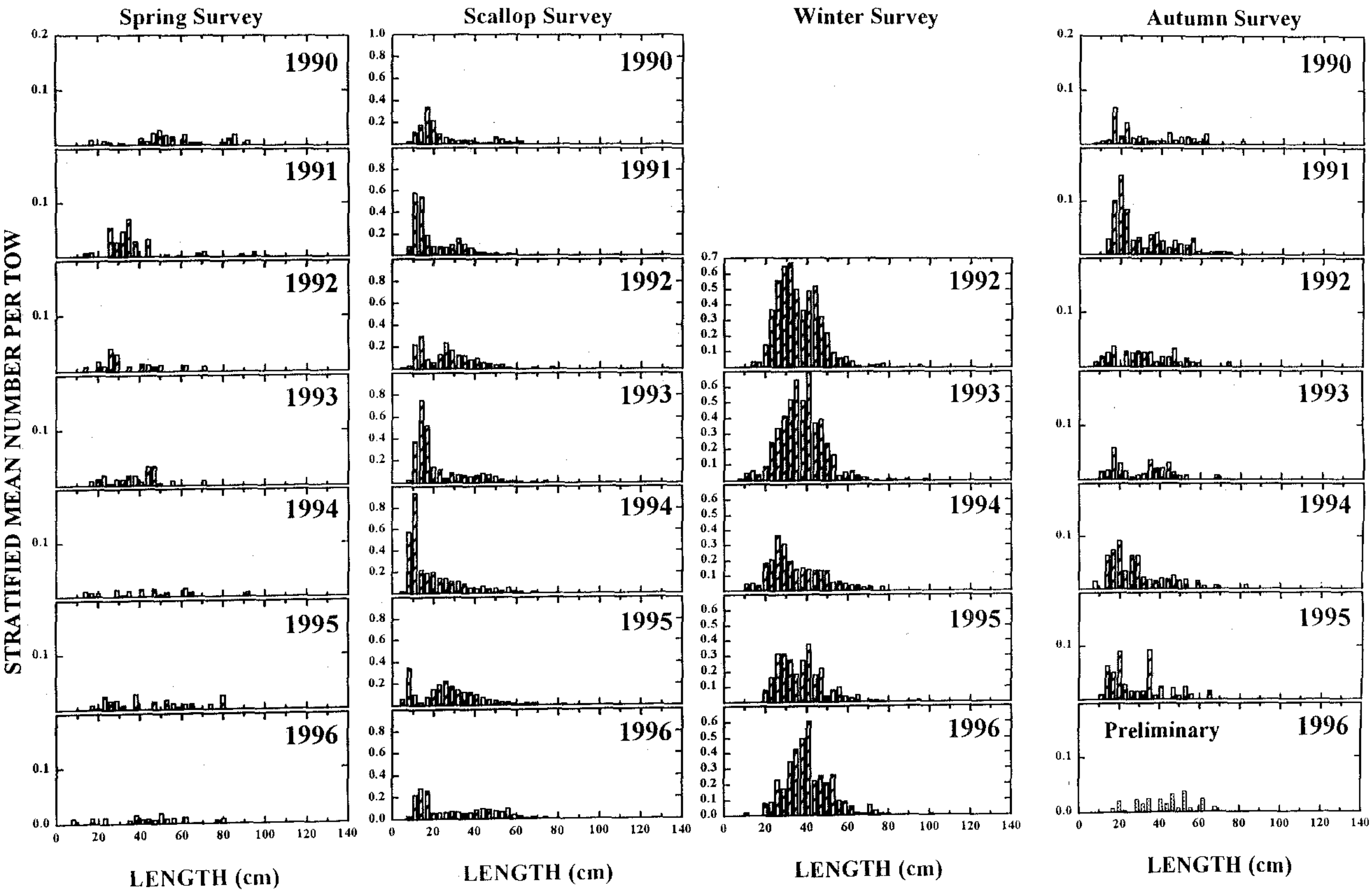

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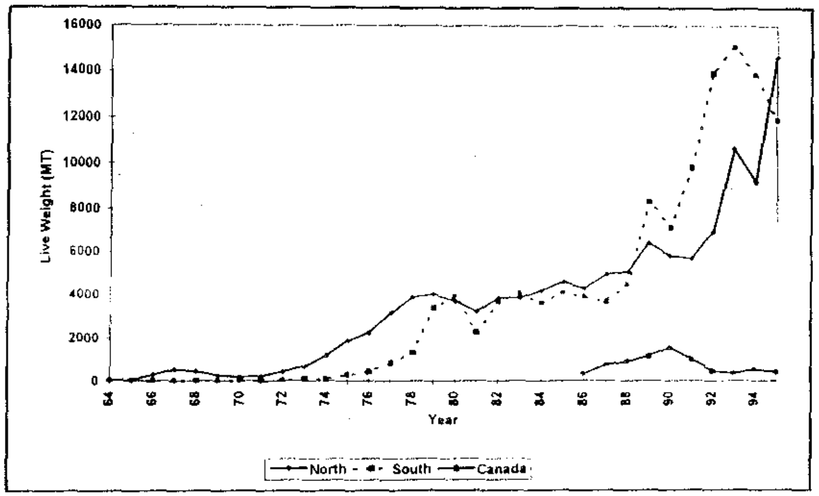


Figure A3. US and Canadian commercial landings (calculated live weight, mt) of goosefish by assessment area (North = Statistical Areas 511-523 plus 561; South = Statistical Areas 524 - 639 excluding 561; Canada = Georges Bank, NAFO Subdivision 5Zc), 1964-1995. US landings as reported in weighout database; 1980, 1994 and 1995 values adjusted as noted in Table A2.

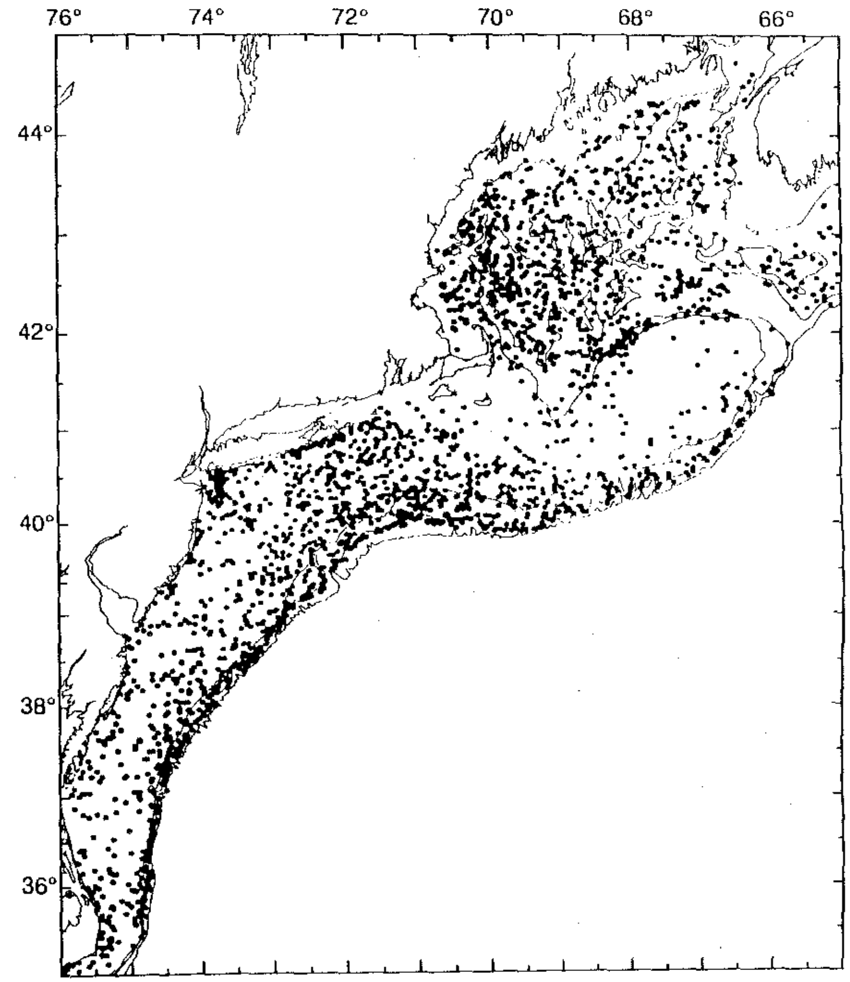


Figure A4. Distribution of catches (presence/absence only) of immature and mature goosefish from NEFSC spring bottom trawl surveys, 1968-1996.

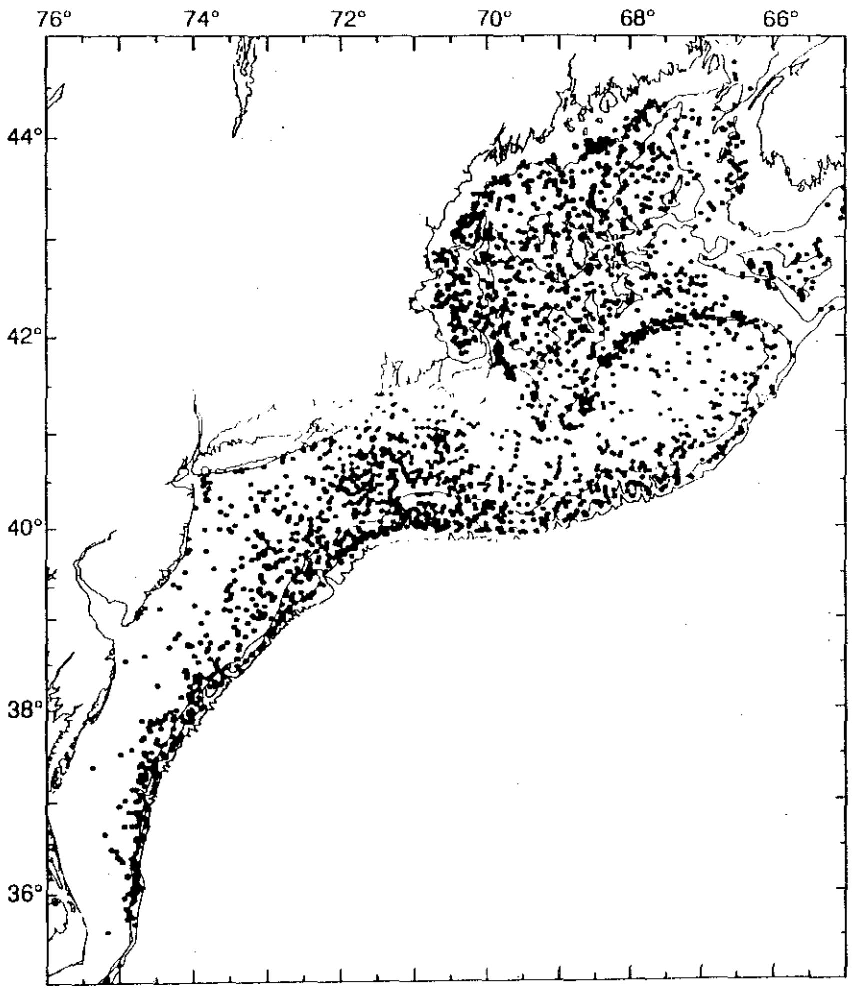


Figure A5. Distribution of catches (presence/absence only) of immature and mature goosefish from NEFSC autumn bottom trawl surveys, 1963-1995.

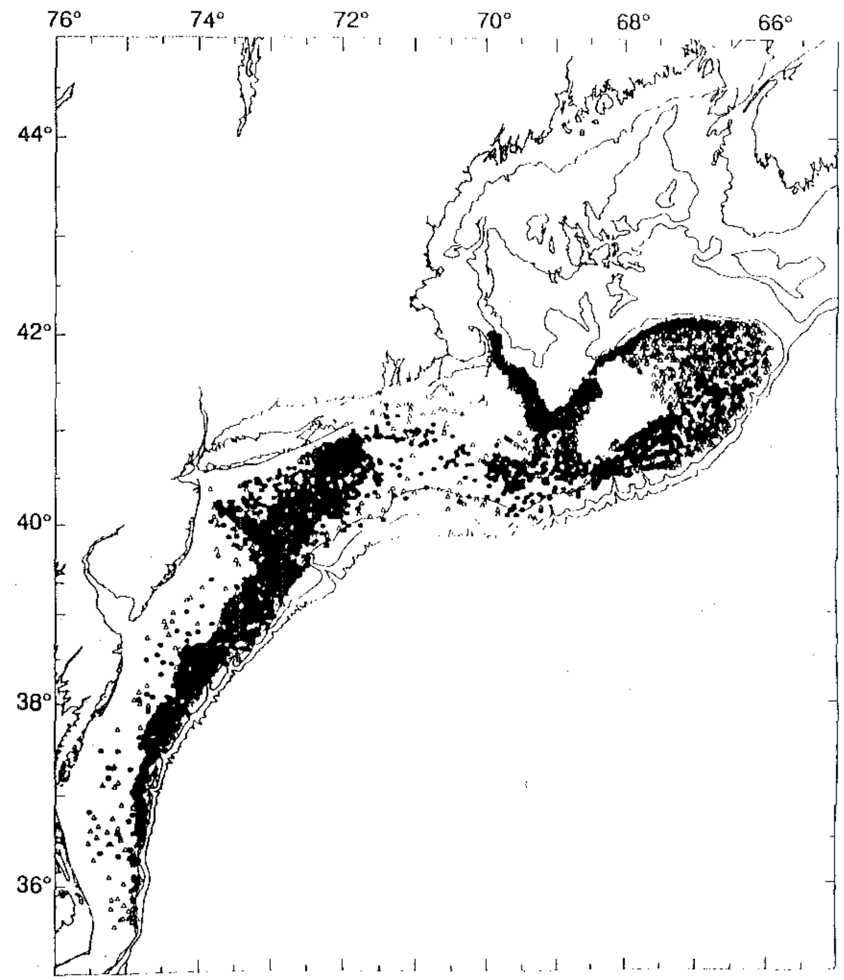


Figure A6. Distribution of catches (presence/absence only) of immature and mature goosefish from NEFSC sea scallop surveys (summer), 1984-1996.

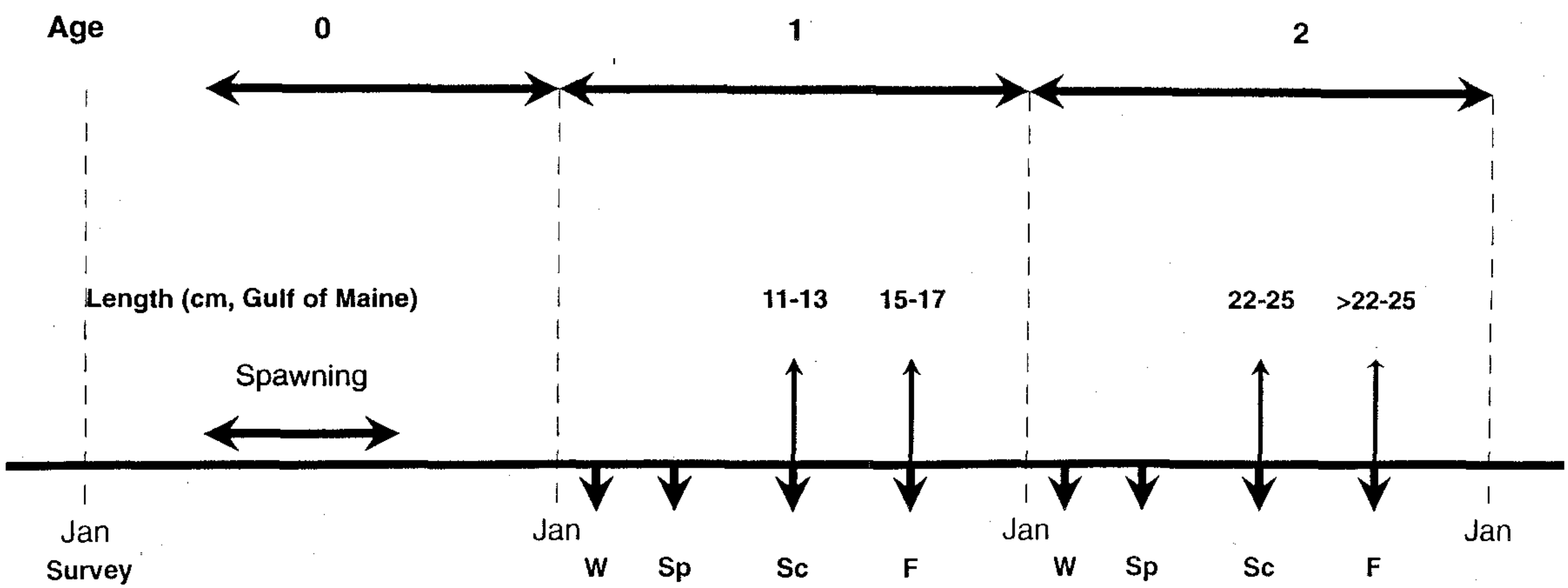
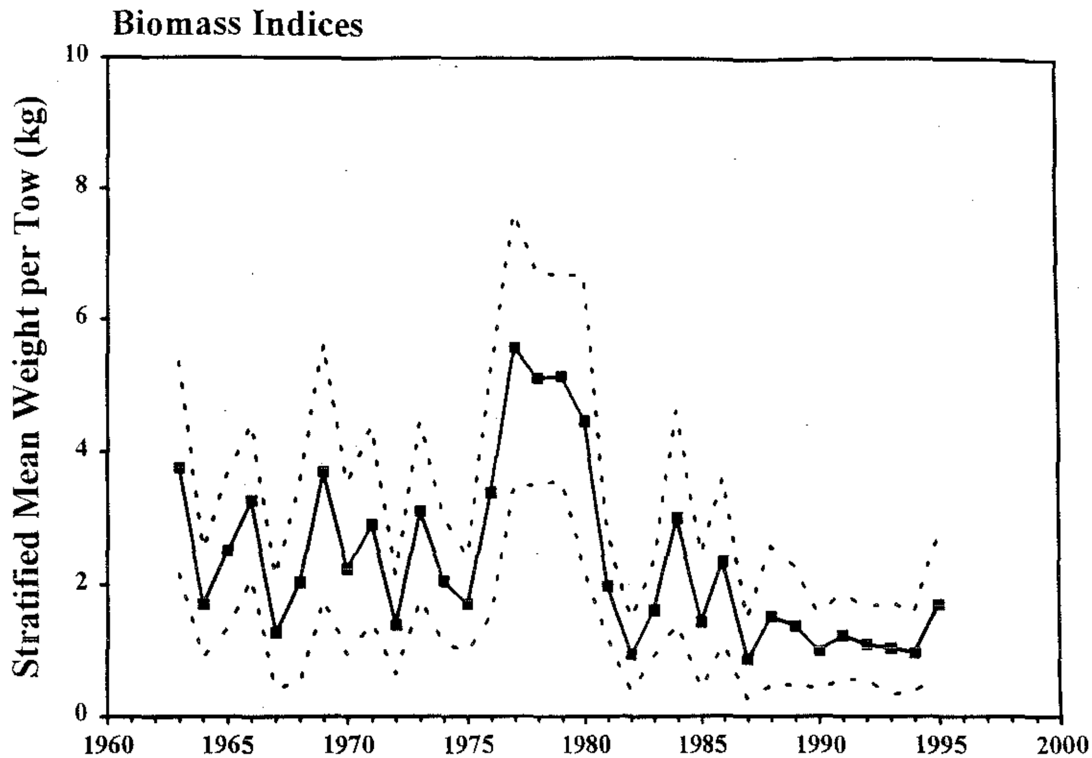


Figure A7. *Ad hoc* "ageing" convention used to identify modes in survey length frequency distributions of goosefish, based on recent growth patterns in the Gulf of Maine, for descriptive purposes only. Survey code: W = NEFSC winter, Sp = NEFSC spring, Sc = NEFSC scallop (same time as ASMFC shrimp), F = NEFSC fall.



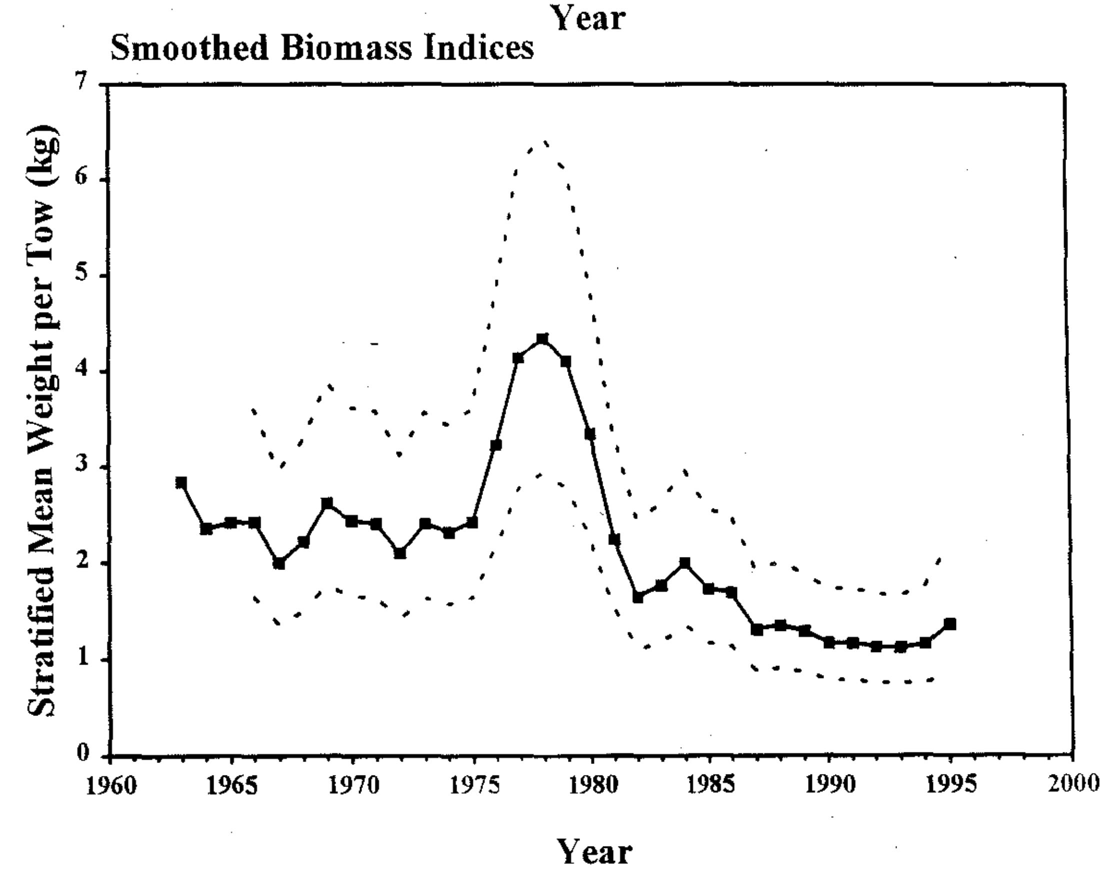
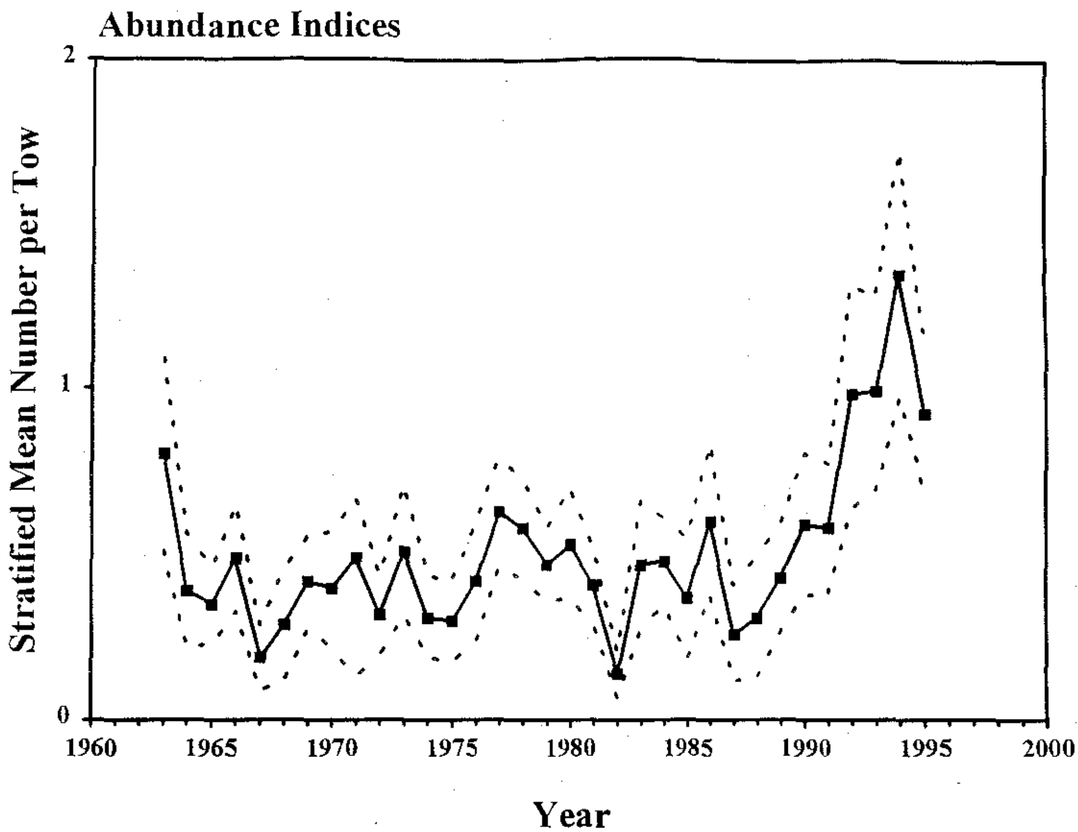


Figure A8. Biomass indices and smoothed indices with the 95% confidence limits from the NEFSC autumn bottom trawl survey for the Gulf of Maine - Northern Georges Bank region for 1963-1995.



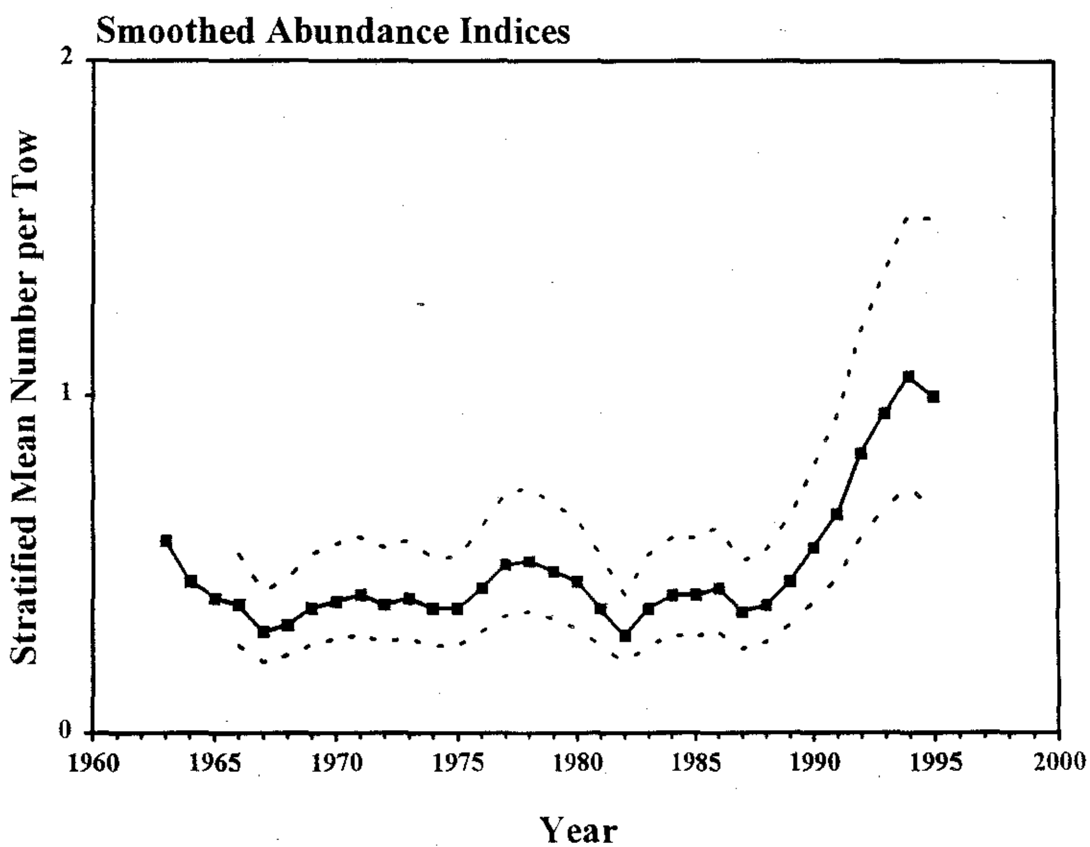


Figure A9. Abundance indices and smoothed indices with the 95% confidence limits from the NEFSC autumn bottom trawl survey for the Gulf of Maine - Northern Georges Bank region for 1963-1995.

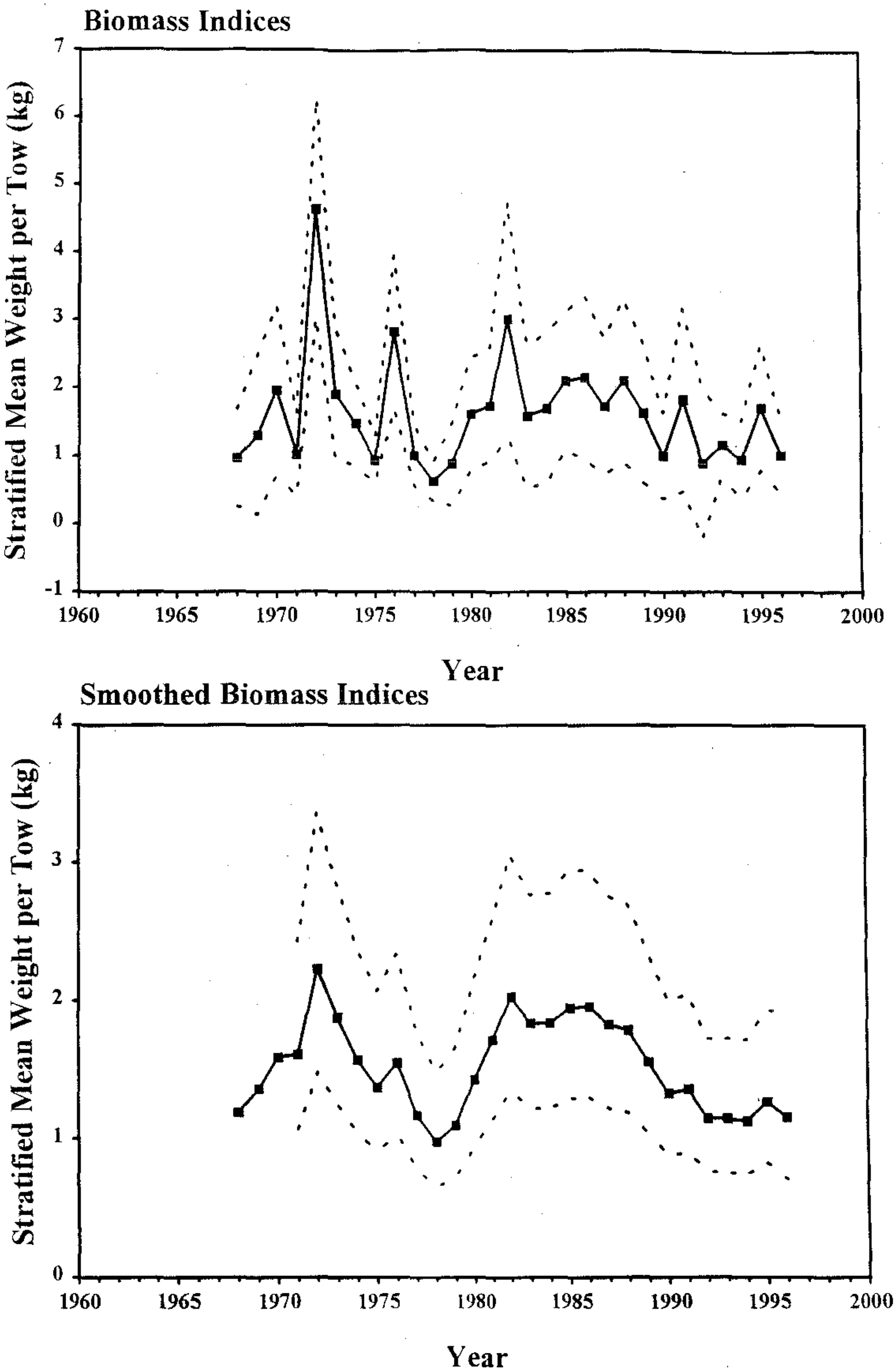
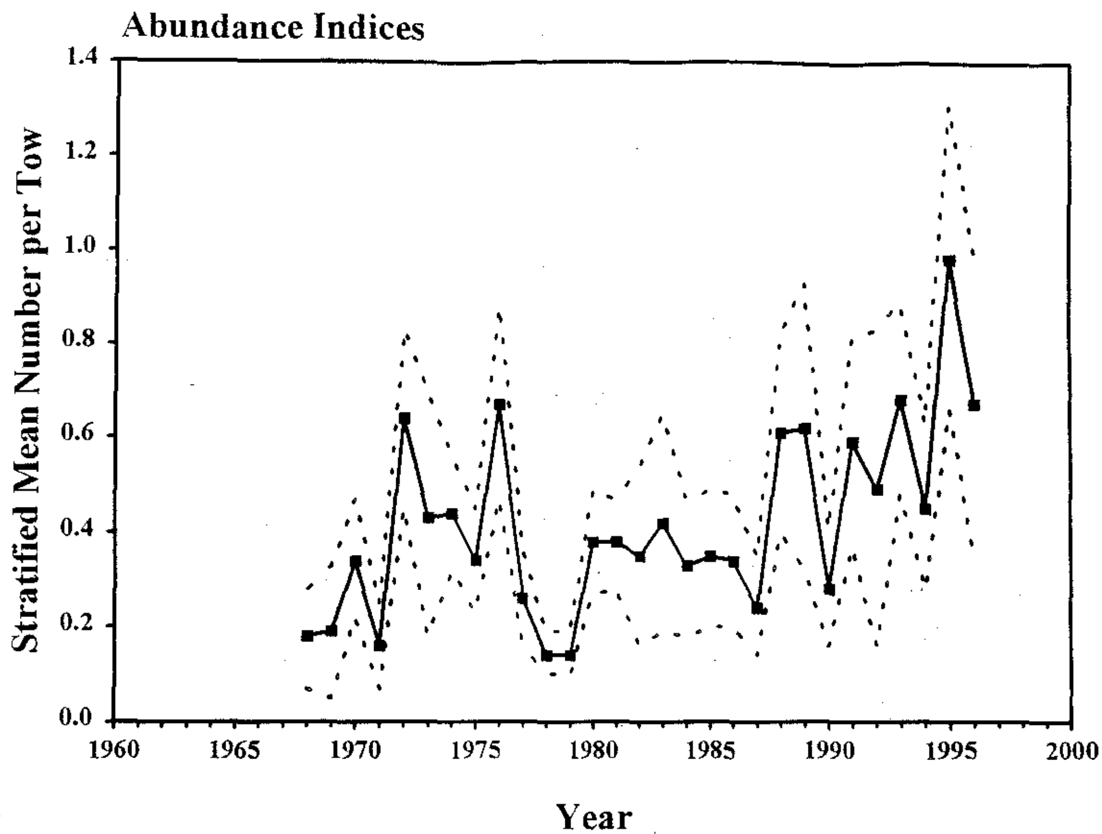


Figure A10. Biomass indices and smoothed indices with the 95% confidence limits from the NEFSC spring bottom trawl survey for the Gulf of Maine - Northern Georges Bank region for 1968-1996.



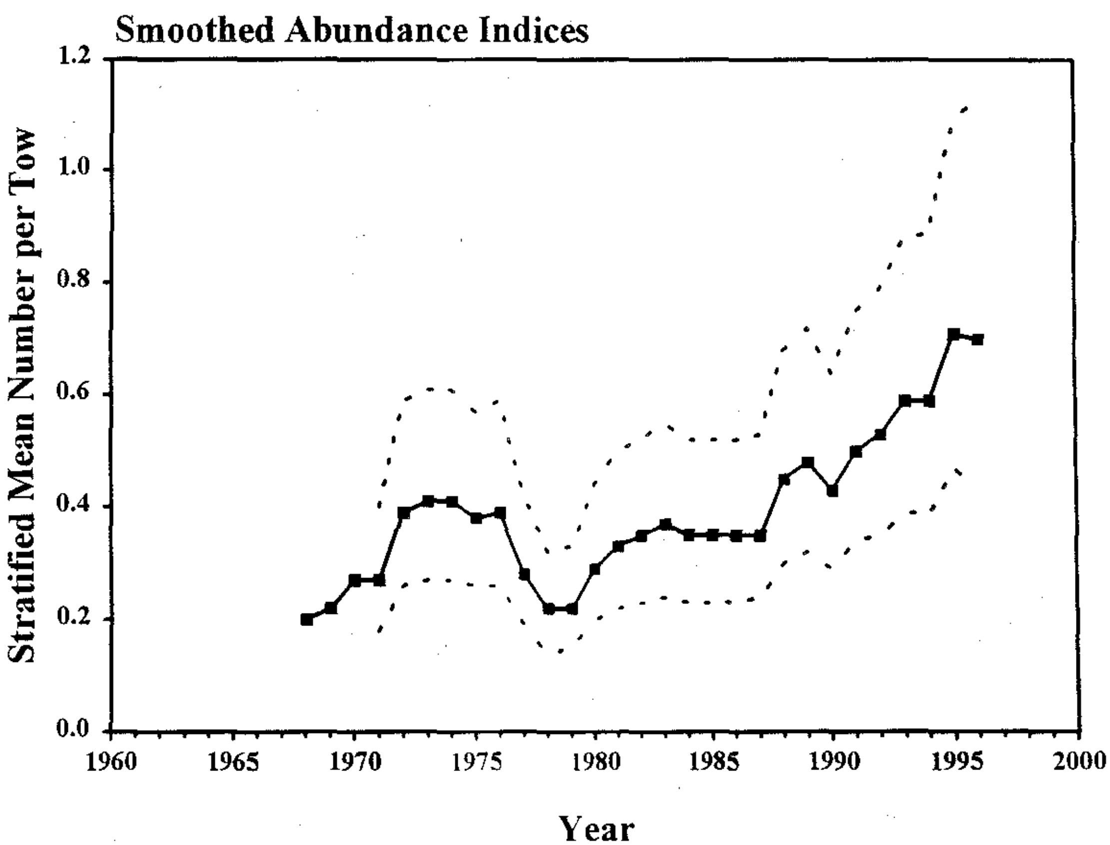


Figure A11. Abundance indices and smoothed indices with the 95% confidence limits from the NEFSC spring bottom trawl survey for the Gulf of Maine - Northern Georges Bank region for 1968-1996.

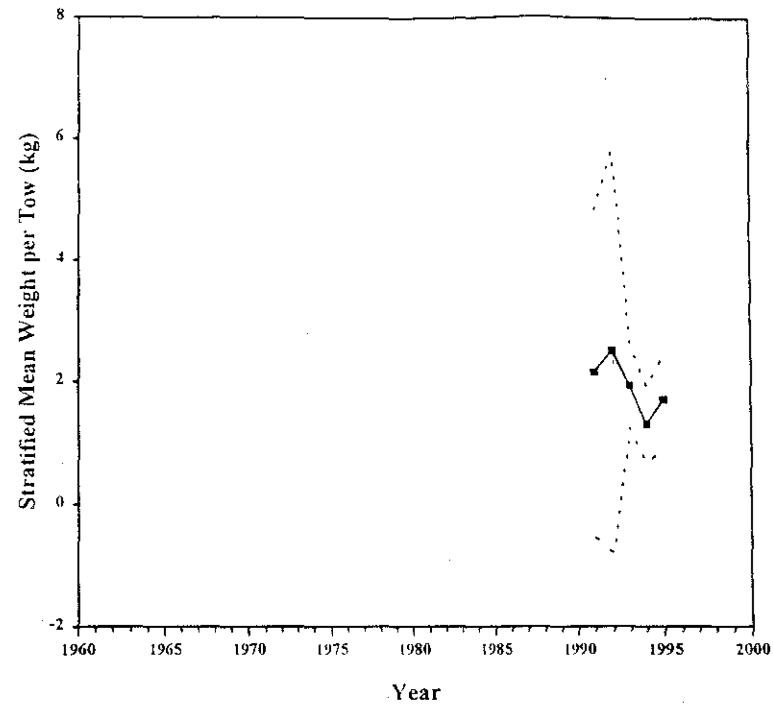


Figure A12. Biomass indices with the 95% confidence limits from the NEFSC summer Gulf of Maine bottom trawl survey for the Gulf of Maine region for 1991-1995.

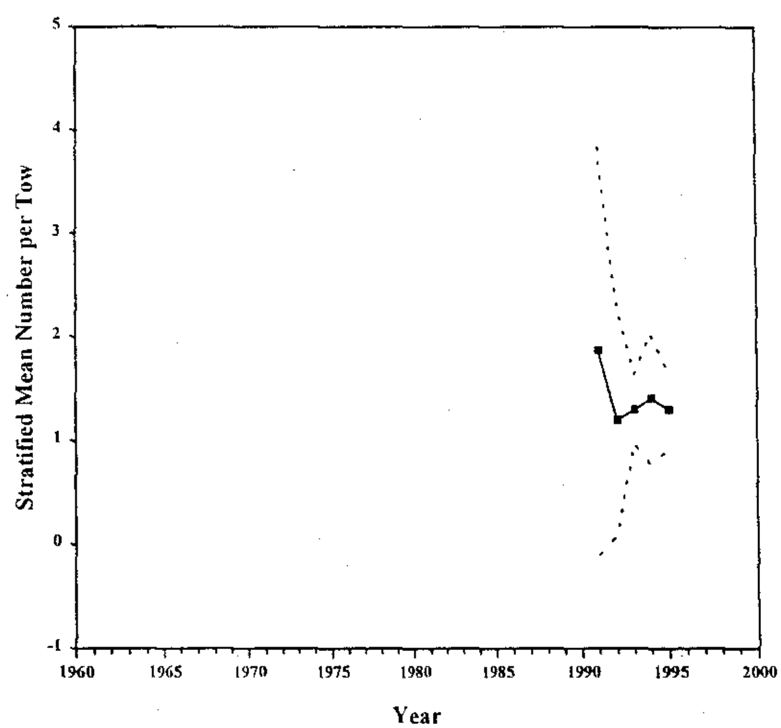
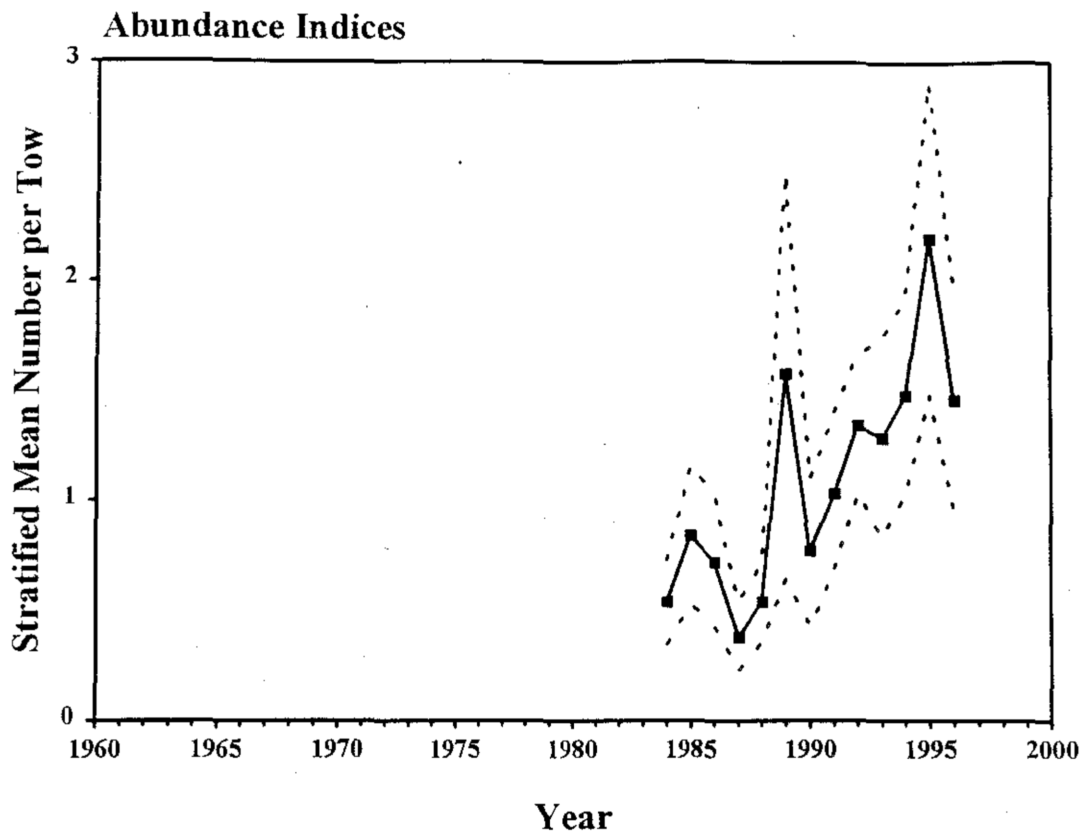


Figure A13. Abundance indices with the 95% confidence limits from the NEFSC summer Gulf of Maine bottom trawl survey for the Gulf of Maine region for 1991-1995.



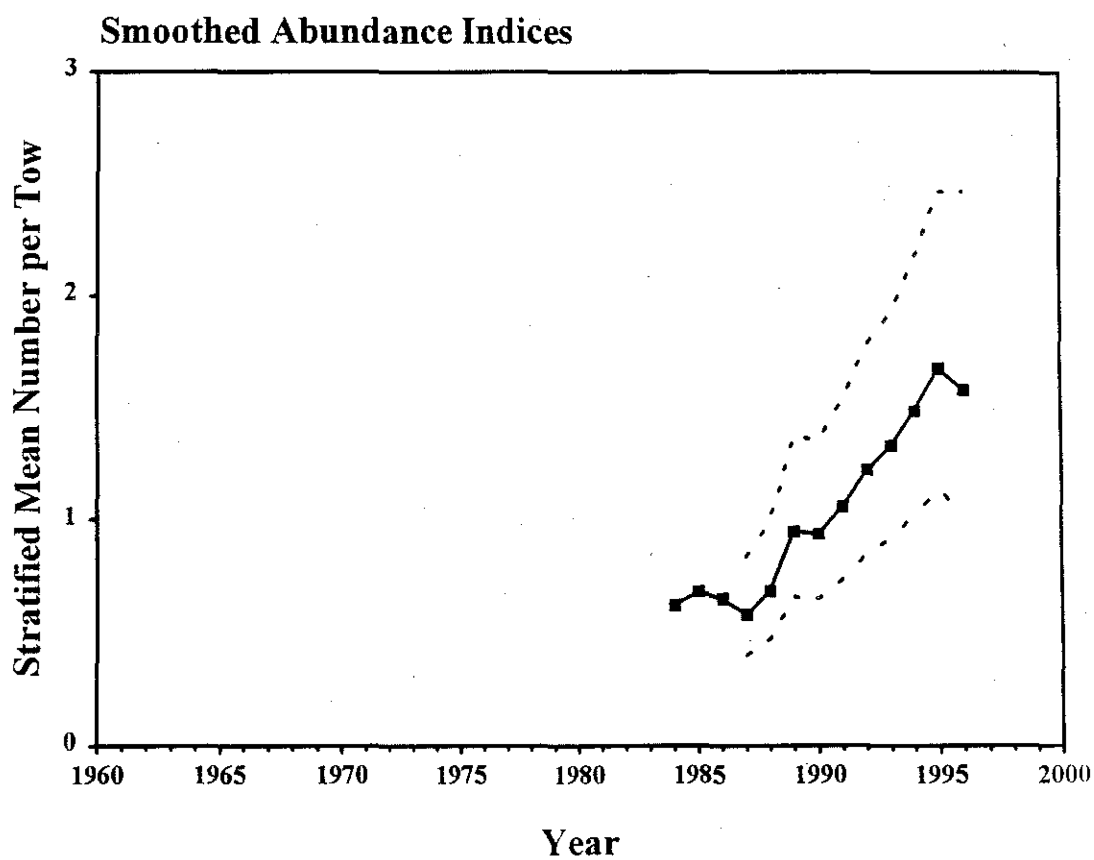


Figure A14. Abundance indices and smoothed indices with the 95% confidence limits from the NEFSC scallop dredge survey for the Northern Georges Bank region for 1984-1996.

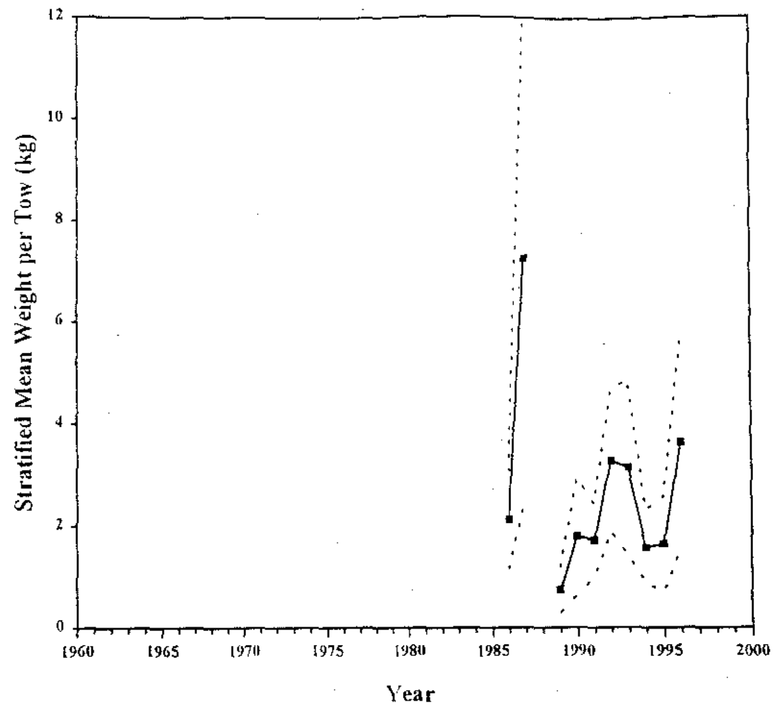


Figure A15. Biomass indices with the 95% confidence limits from the ASMFC summer shrimp trawl survey for the Gulf of Maine region for 1986-1996.

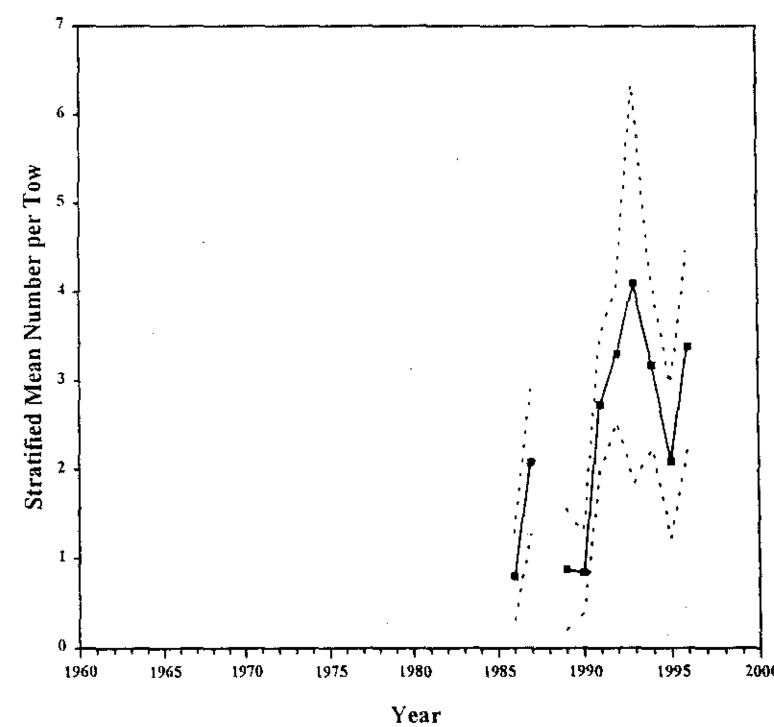


Figure A16. Abundance indices with the 95% confidence limits from the ASMFC summer shrimp trawl survey for the Gulf of Maine region for 1986-1996.

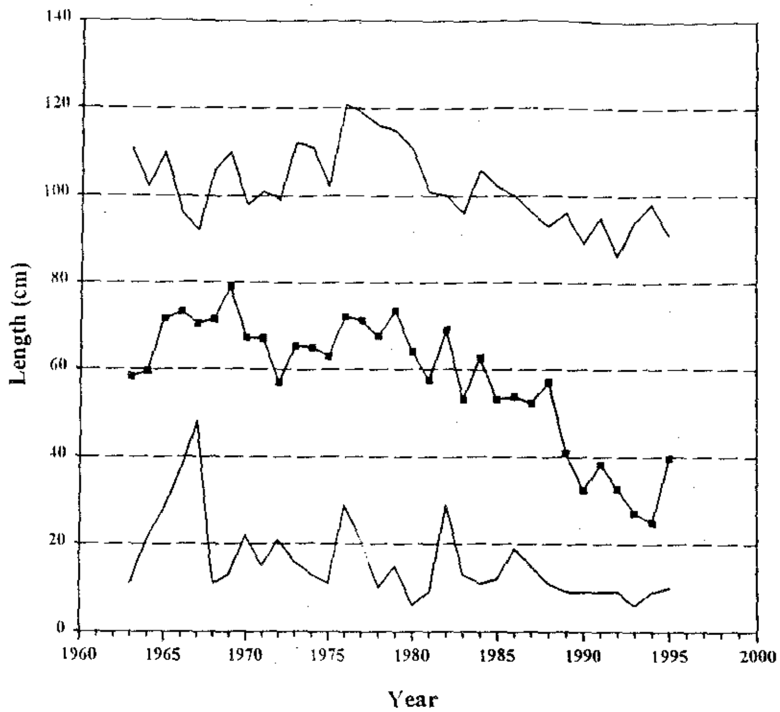


Figure A17. Minimum, mean, and maximum lengths for the Gulf of Maine - Northern Georges Bank region from the NEFSC autumn bottom trawl survey, 1963-1995.

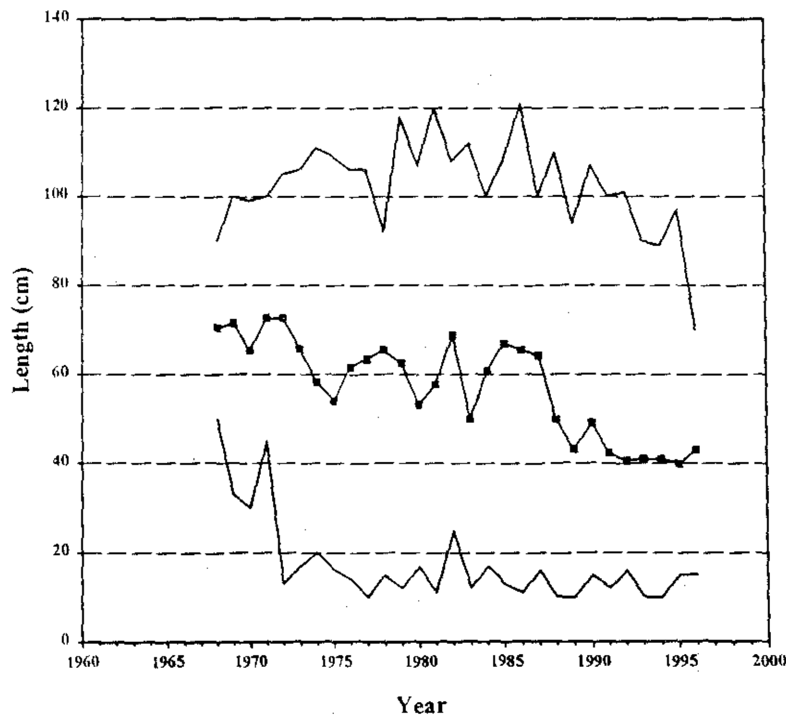


Figure A18. Minimum, mean, and maximum lengths for the Gulf of Maine - Northern Georges Bank region from the NEFSC spring bottom trawl survey, 1968-1996.

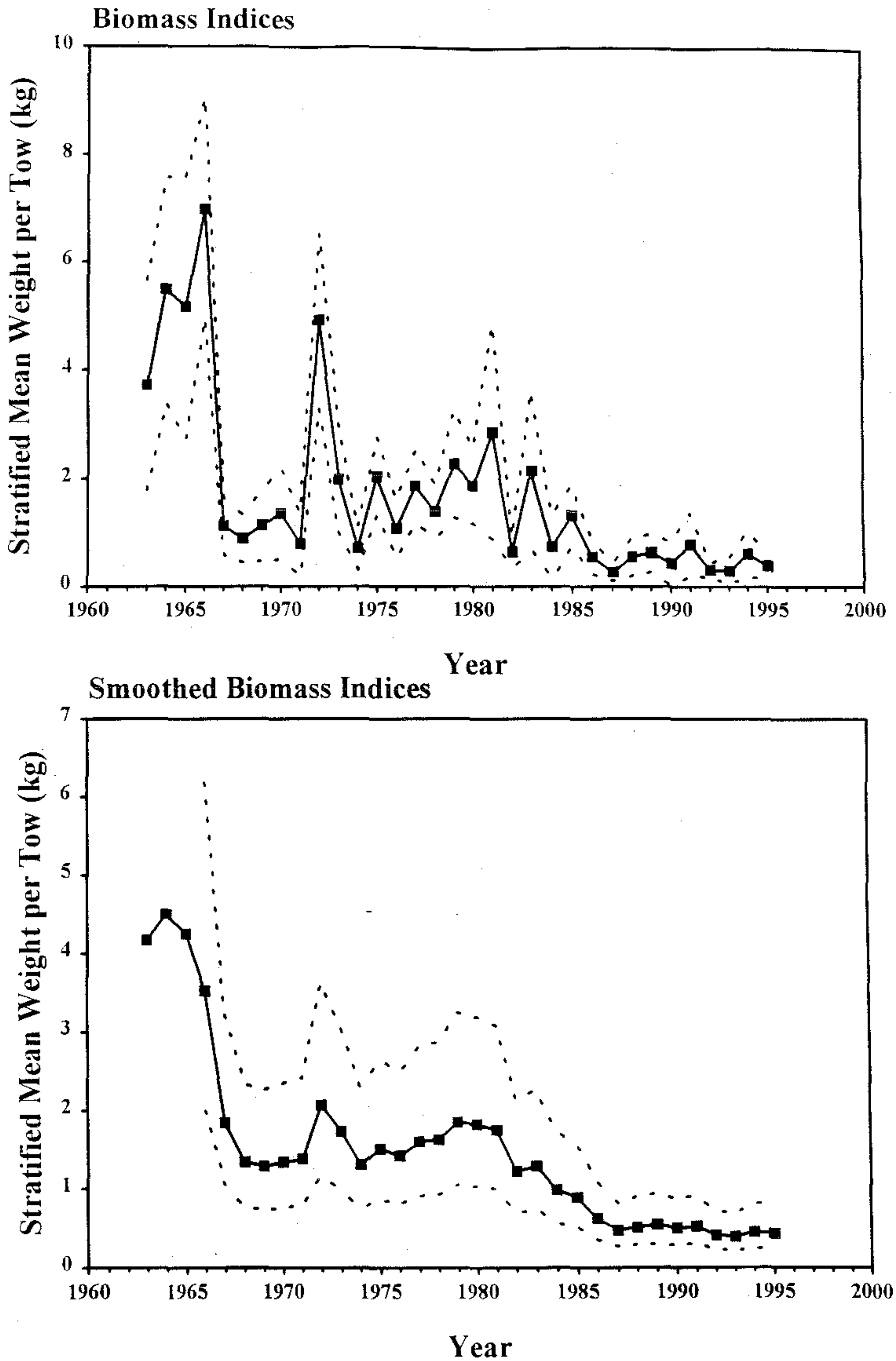


Figure A19. Biomass indices and smoothed indices with the 95% confidence limits from the NEFSC autumn bottom trawl survey for the Southern Georges Bank - Mid-Atlantic region for 1963-1995.

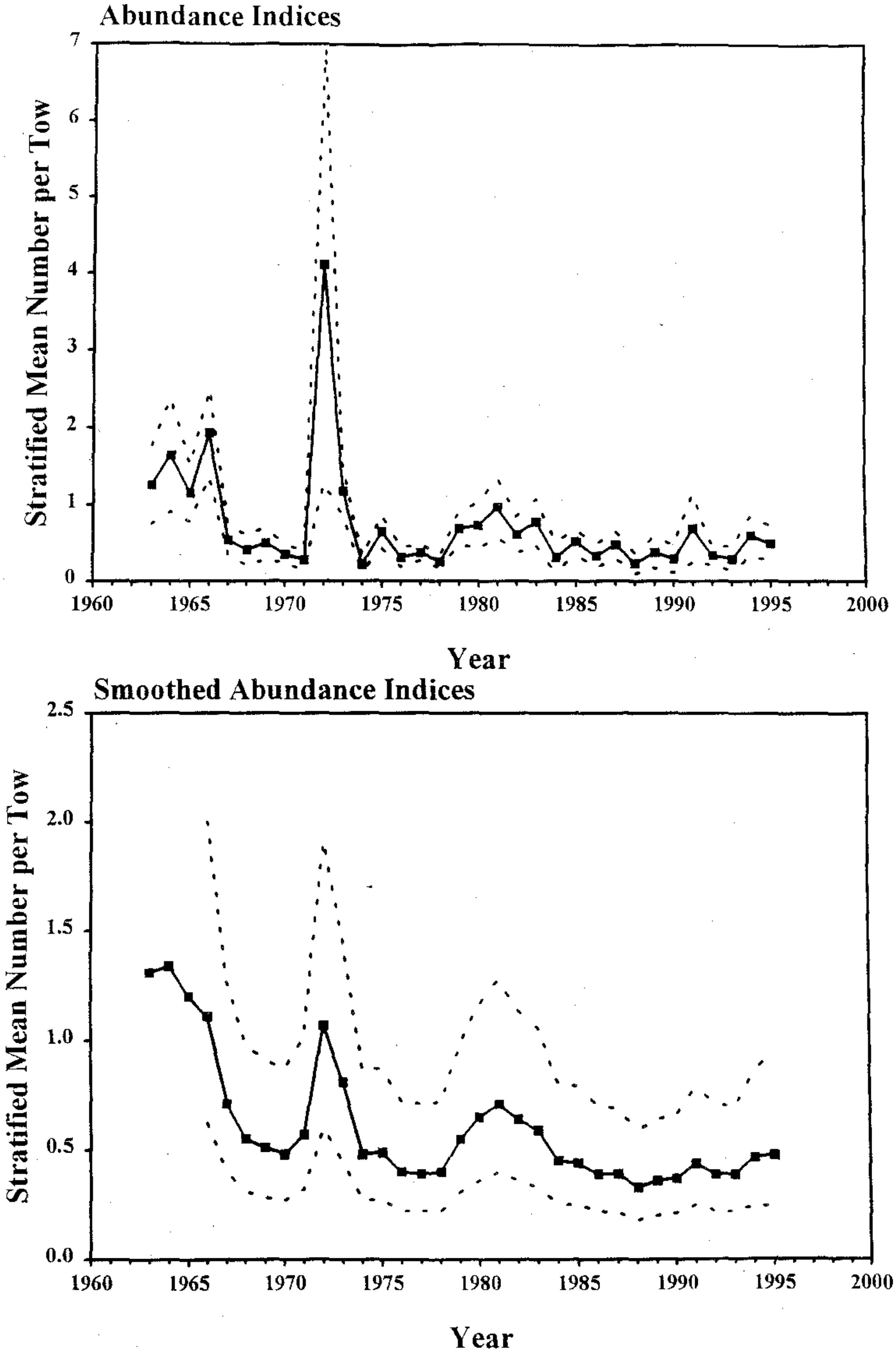


Figure A20. Abundance indices and smoothed indices with the 95% confidence limits from the NEFSC autumn bottom trawl survey for the Southern Georges Bank - Mid-Atlantic region for 1963-1995.

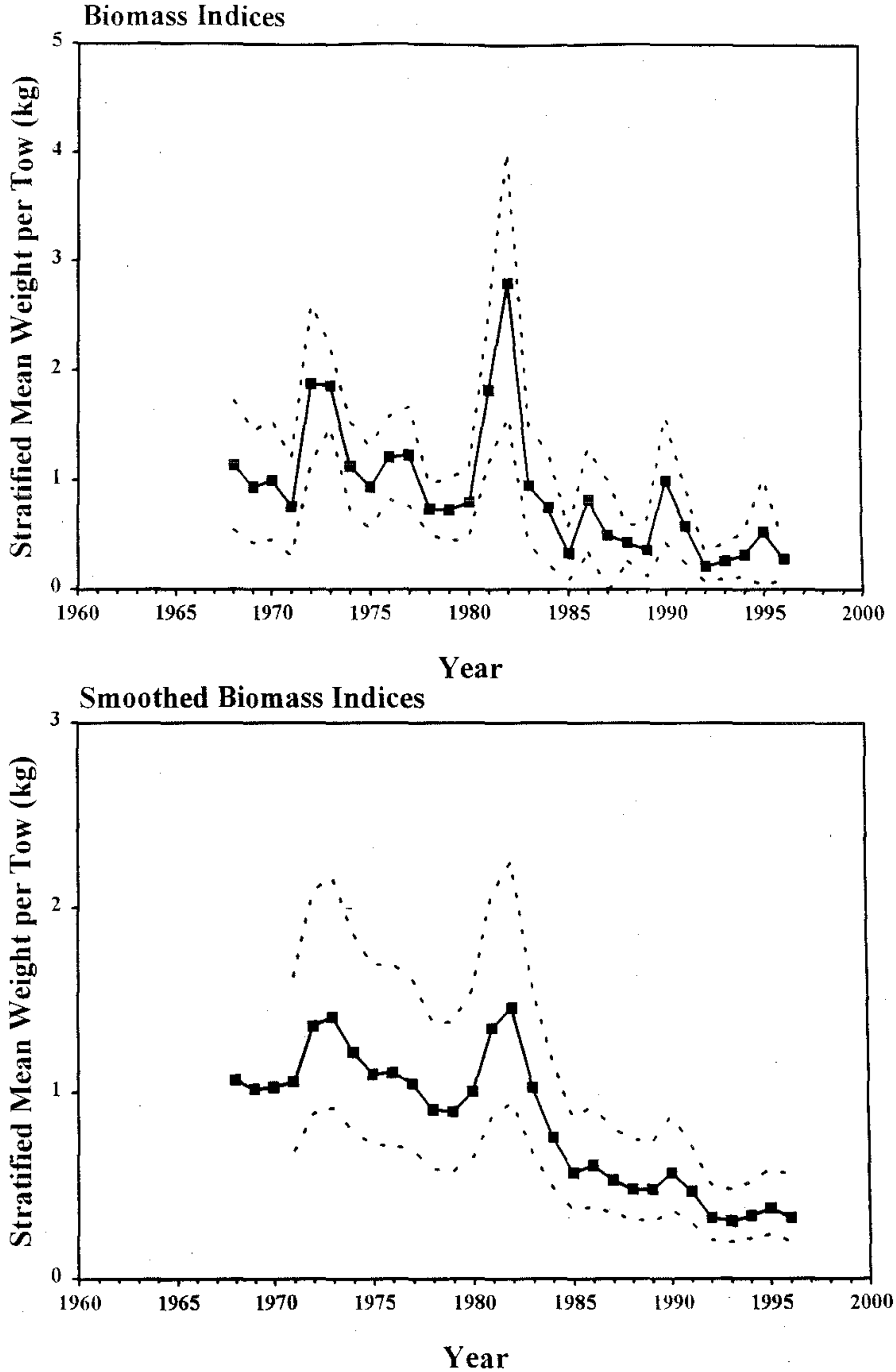
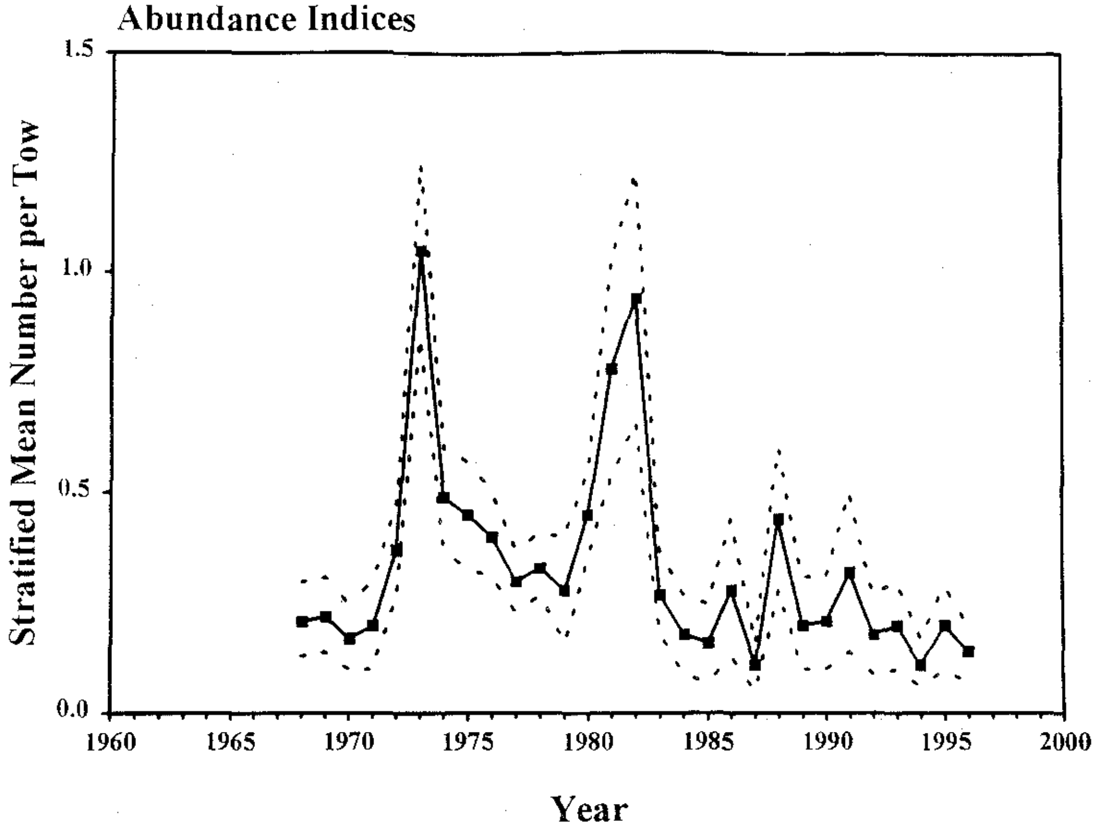


Figure A21. Biomass indices and smoothed indices with the 95% confidence limits from the NEFSC spring bottom trawl survey for the Southern Georges Bank - Mid-Atlantic region for 1968-1996.



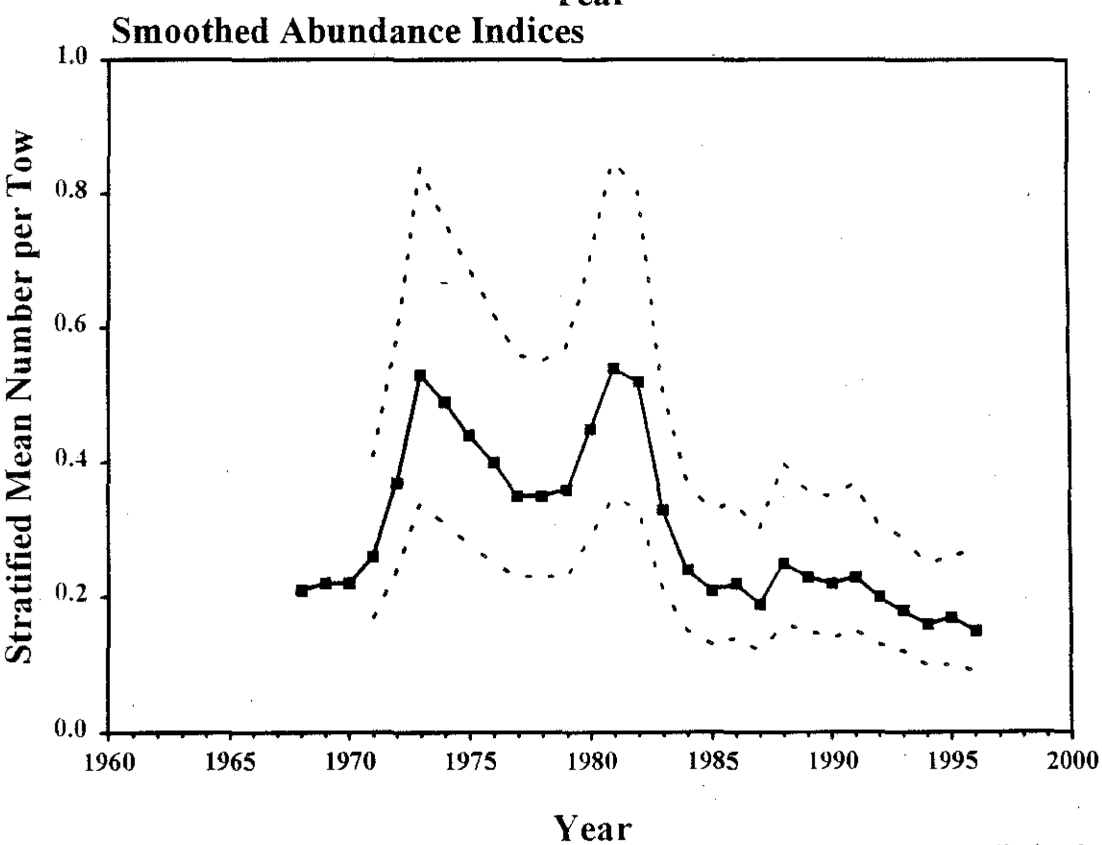


Figure A22. Abundance indices and smoothed indices with the 95% confidence limits from the NEFSC spring bottom trawl survey for the Southern Georges Bank - Mid-Atlantic region for 1968-1996.

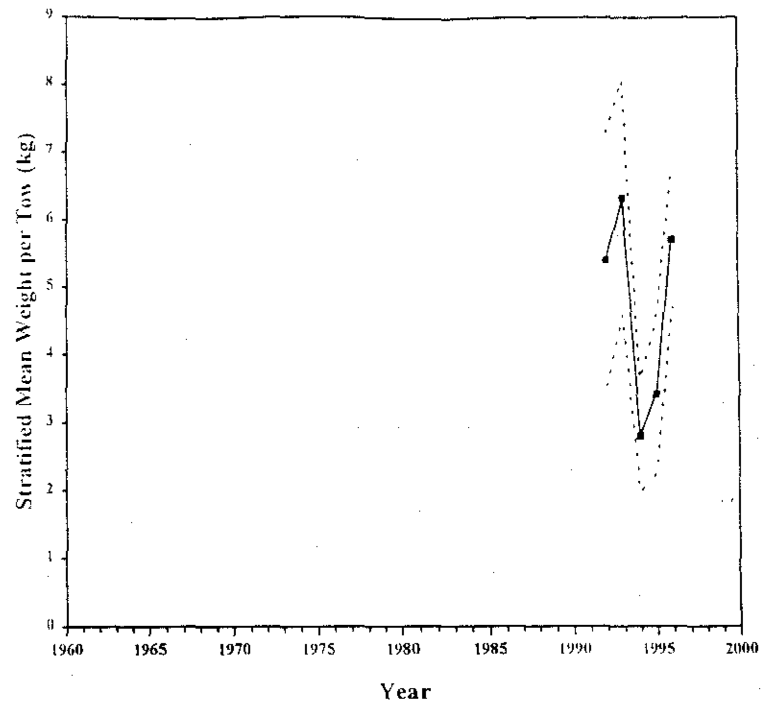


Figure A23. Biomass indices with the 95% confidence limits from the NEFSC winter flatfish survey for the Southern Georges Bank - Mid-Atlantic region for 1992-1996.

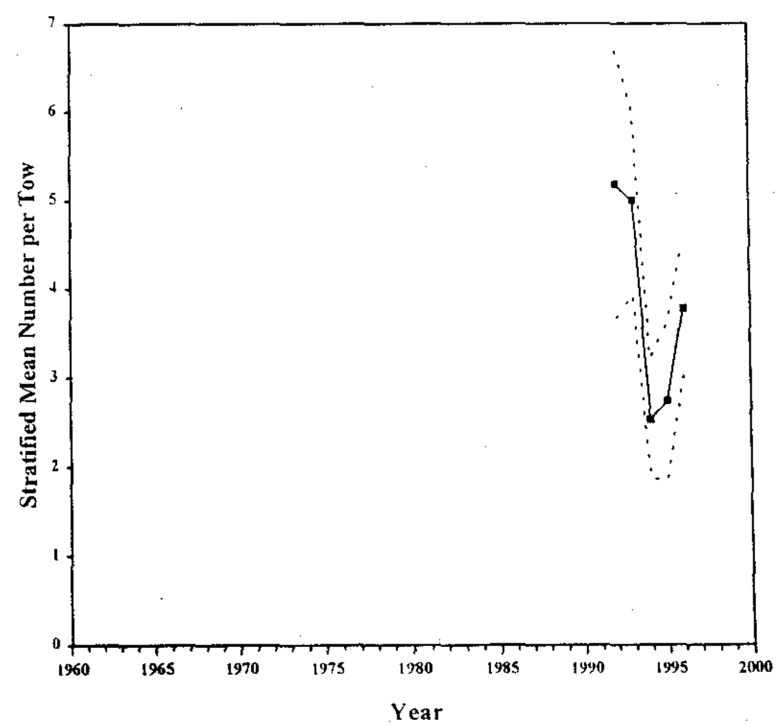


Figure A24. Abundance indices with the 95% confidence limits from the NEFSC winter flatfish survey for the Southern Georges Bank - Mid-Atlantic region for 1992-1996.

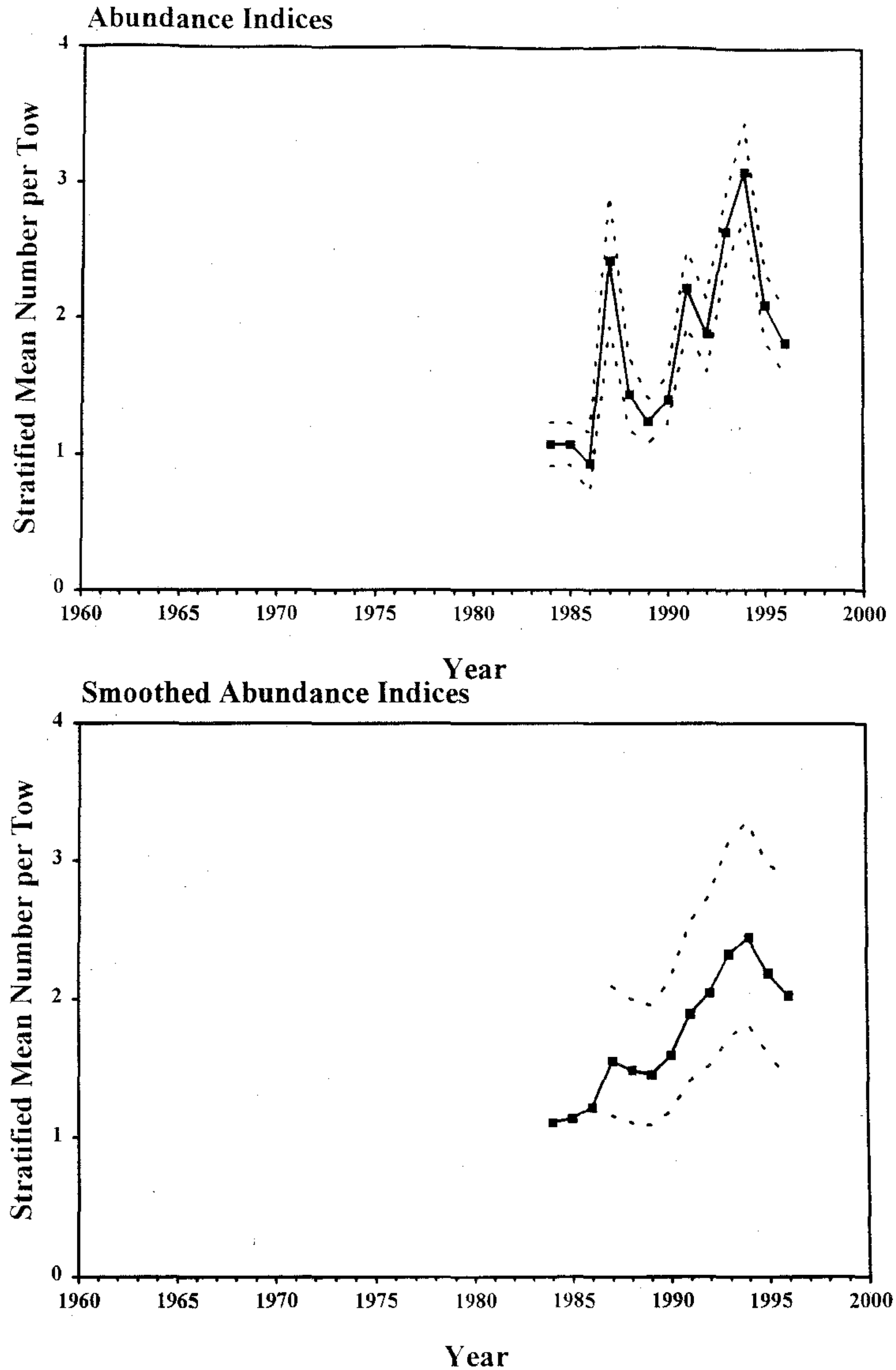


Figure A25. Abundance indices and smoothed indices with the 95% confidence limits from the NEFSC scallop dredge survey for the Southern Georges Bank - Mid-Atlantic region for 1984-1996.

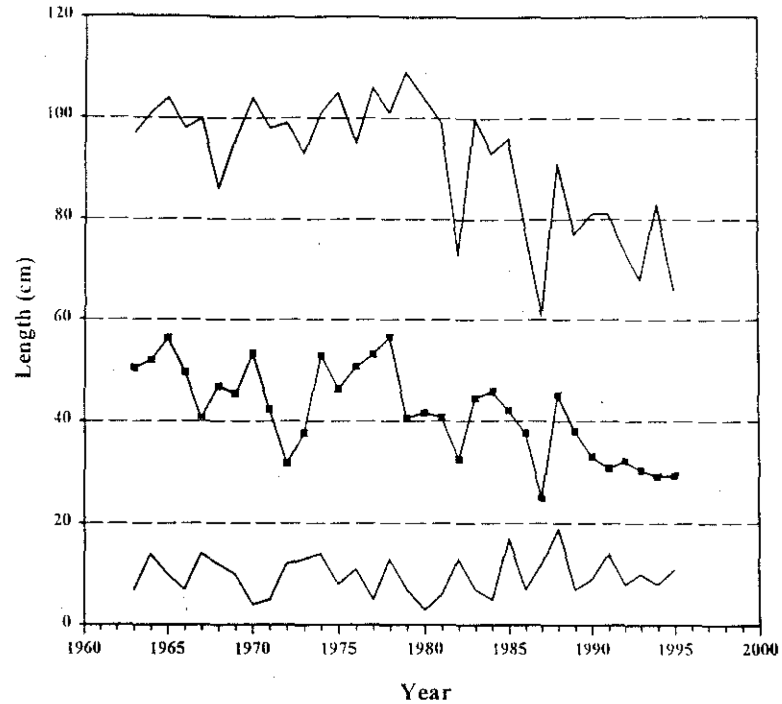


Figure A26. Minimum, mean, and maximum lengths for the Southern Georges Bank - Mid-Atlantic region from the NEFSC autumn bottom trawl survey, 1963-1995.

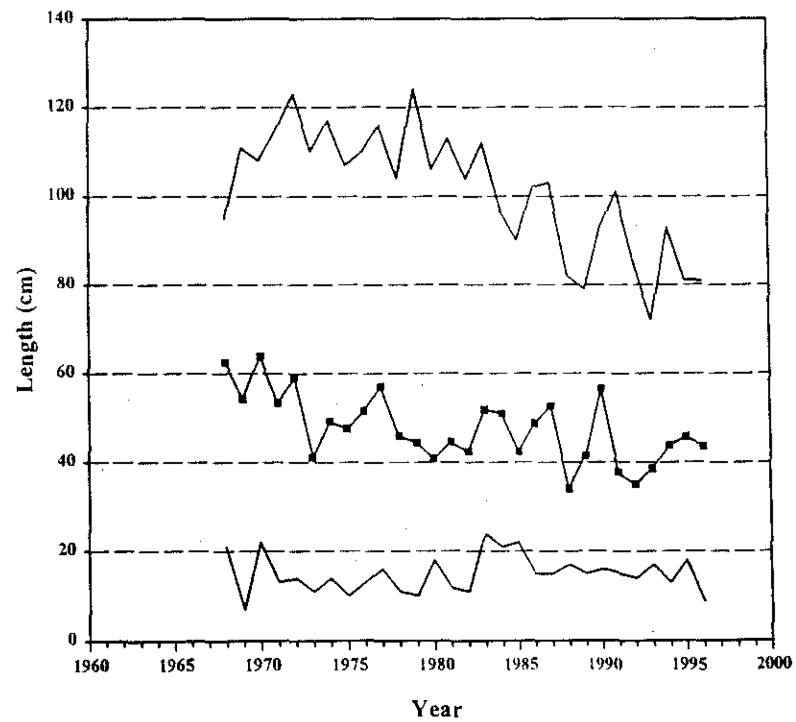


Figure A27. Minimum, mean, and maximum lengths for the Southern Georges Bank - Mid-Atlantic region from the NEFSC spring bottom trawl survey, 1968-1996.

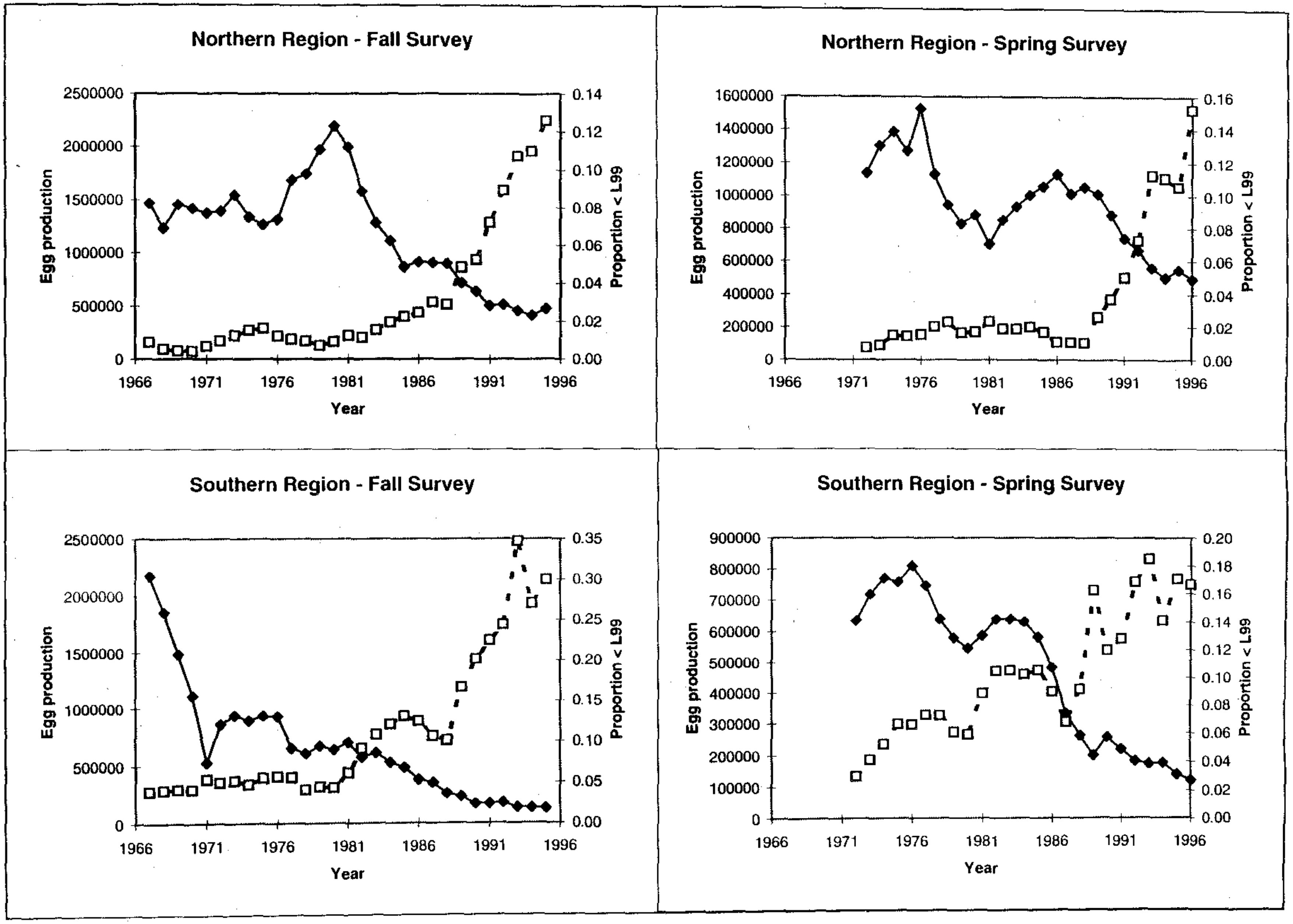
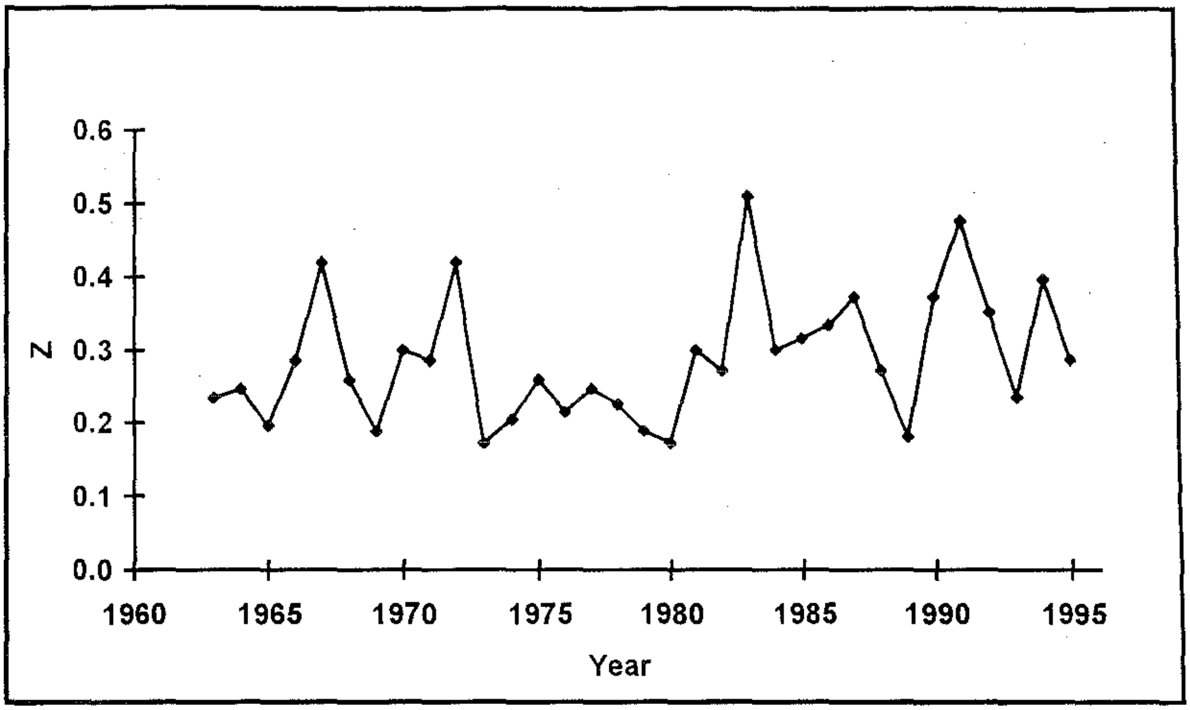


Figure A28. Indices of spawning stock biomass of goosefish, 1964-1966, by region and survey. Egg production (primary Y axis, solid line) is relative index of total egg production, based on composite length frequency distributions from research survey indices of catch per tow at length, proportion mature at length and fecundity at length. Year represents the terminal year of a 5-year pooled length frequency sample. Fraction of SSB from immature goosefish (secondary Y axis, dashed line) is proportion of egg production generated by fish smaller than length at 99% maturity.



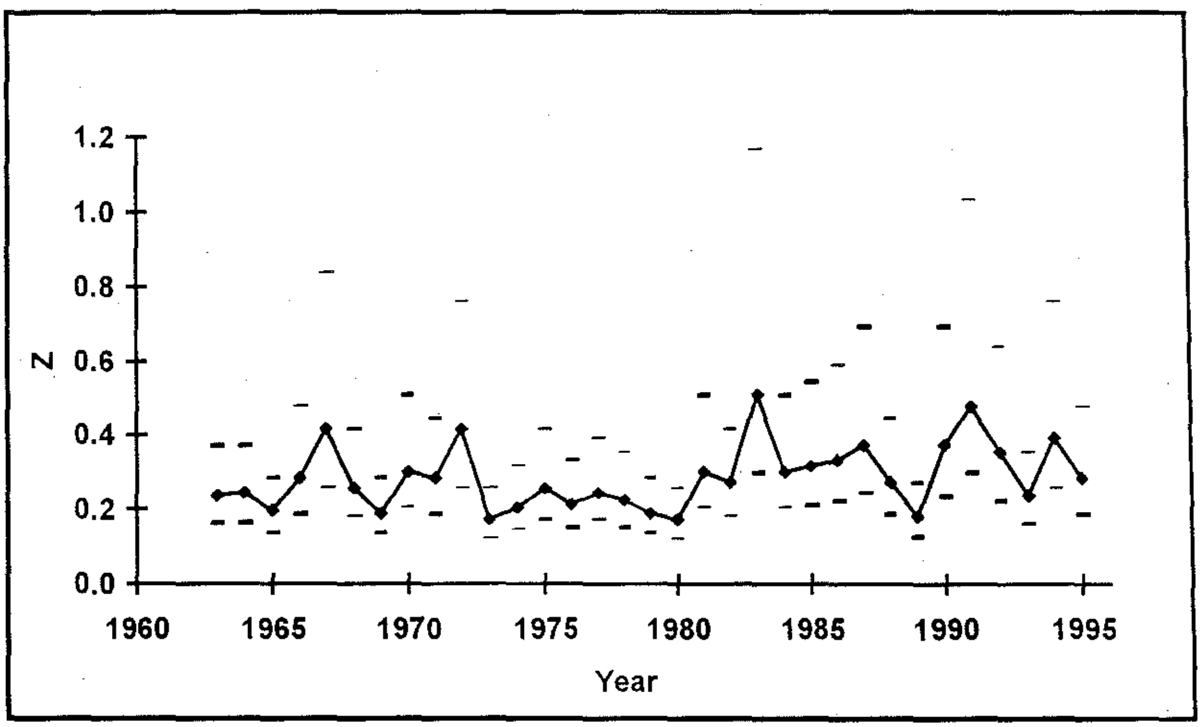


Figure A29. Total instantaneous mortality (Z) for goosefish, northern region, 1963-1995, Beverton-Holt analysis; and minimum estimates of 95% confidence intervals.

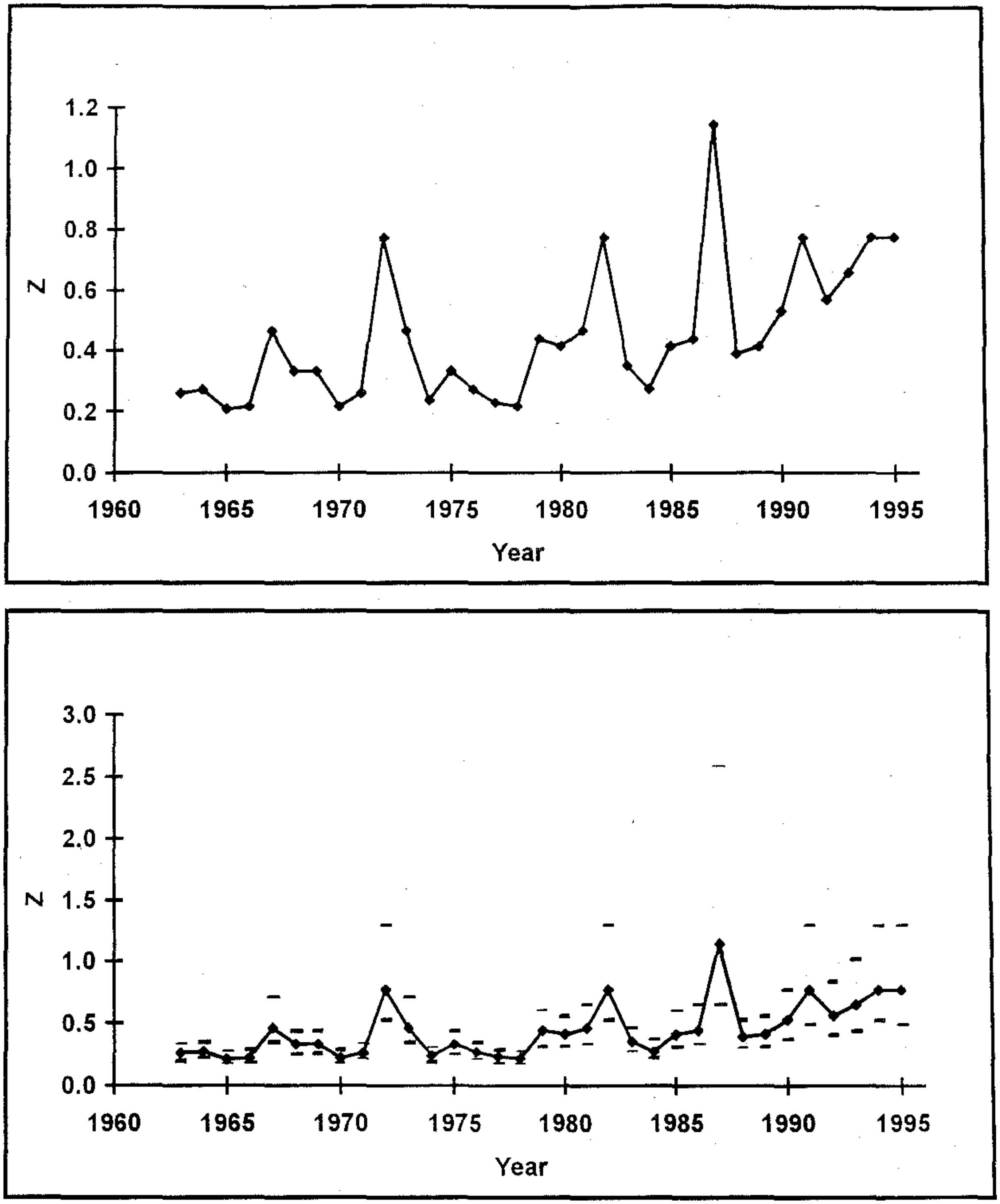


Figure A30. Total instantaneous mortality (Z) for goosefish, southern region, 1963-1995, Beverton-Holt analysis; and minimum estimates of 95% confidence intervals.

B. SEA SCALLOP

Terms of Reference

The following terms of reference were addressed for sea scallops:

a. Provide updated indices of abundance and size composition through 1996, by assessment area, for sea scallop populations.

b. Evaluate size composition of catches and landings based on sea sampling and port sampling information.

c. To the extent feasible, allocate recent catches to assessment areas and evaluate trends in abundance and fishing mortality rates for appropriate assessment regions.

d. To the extent feasible, evaluate the efficiency of technical management measures (e.g., minimum dredge ring size, crew size, closed areas, and other gear restrictions) on sea scallop resources.

Introduction

Sea scallops (*Placopecten magellanicus*) are found in the Northwest Atlantic Ocean from North Carolina to Newfoundland along the continental shelf of North America. Most US commercial landings are taken at depths between 40 and 200 m (22- 110 fm) on Georges Bank and in the Mid-Atlantic (NEFSC 1993). Sea scallops grow rapidly during their first several years of life with a 50-80% increase in shell height and a quadrupling in meat weight between ages 3 and 5. Maximum size is about 23 cm, but scallops larger than 17 cm are rare. Sexual maturity commences at age 2 and as small as 25 mm, but scallops less than 4 years old probably contribute little to total egg production (NEFSC 1993). Spawning generally occurs in the late summer and early autumn, but biannual spawning (twice per year) has been observed in the early spring in the Delmarva Region (DuPaul *et al.* 1989). Mid-winter spawning off Georges Bank may also occur (Almeida *et al.* 1994). Eggs are buoyant, and the larvae remain in the water column for 4-6 weeks before settling. During this period, considerable transport of larvae can occur depending on prevailing current patterns.

The previous assessment of the US sea scallop population was conducted in June 1995 at SAW-20 (NEFSC 1995). That assessment incorporated commercial catch data through 1993 and research survey data through 1994. Effects of significant management changes that began in 1994 could not yet be measured, and the assessment was considered to be a summary of resource conditions prior to the implementation of the provisions of Amendment 4 to the Atlantic Sea Scallop Fishery Management Plan. Since the last assessment, major changes have occurred in data collection procedures and fishery regulations. This assessment describes these changes and their importance for resource assessment.

Procedures used to estimate landings by weight and numbers were significantly different for 1994-1996 than for previous years. Three major changes began in 1994. First, mandatory logbooks replaced the routine interviews of fishermen at major ports as a means of monitoring catches and fishing effort by area. Second, the transition to logbooks coincided with changes in responsibilities of NMFS port agents. From the standpoint of stock assessments, the most important change was a decrease in the number of biological samples collected. For the scallop fishery, this meant that samples of shells from the last tow of a fishing trip were no longer collected routinely. Finally, the overwhelming volume of vessel trip reports (VTR) created a severe backlog in the entry and auditing of landings data. These changes and the absence of a parallel data collection system forced a reconsideration of the methodology for catch estimation by area. New methods were required to account for the uncertainty in the revised data sets.

Superimposed on changes to commercial fisheries data collection procedures were new regulations for the scallop fishery under Amendment 4. These included elimination of minimum meat count regulations, an increase in ring size to 3.5 inches, reductions in the maximum crew size, and reductions in the allowable days at sea. All of these measures were designed to reduce total fishing mortality and improve the productivity of the resource by delaying the age at entry into the fishery.

Perhaps the most significant change in the scallop fishery was the establishment of two closed areas on Georges Bank and one in Southern New England. These closures, external to the Scallop Management Plan, were designed to protect depleted cod, haddock, and yellowtail flounder stocks. Scallop dredges were included in the fishing ban owing to their propensity to catch juvenile flatfish and other species low in abundance. The closed areas represented about 50% of the main scallop areas on Georges Bank and in the Great South Channel. Both of the closed areas on Georges Bank represented areas historically high in abundance. Since the closed areas were not accompanied by additional reductions in fishing effort, vessels redirected their efforts to open areas.

Another factor influencing the redirection of fishing effort was the presence of relatively strong 1990 and 1991 year classes in the Mid-Atlantic region and weak year classes on Georges Bank.

The cumulative effects of the changes in the fishery, data collection methodology, and underlying biological variation were substantial. This assessment is the first within the SAW process to utilize the 1994-1996 commercial data. Many changes from the previous assessment methodologies were necessitated by the factors described above. Nonetheless, this assessment illustrates the major positive effects of closed areas to protect sessile species, the negative consequences of redirected fishing effort to open areas, and the immediate need to improve data collection procedures. This assessment is also important in the management process because Amendment 4 requires an evaluation of the efficacy of measures that have been implemented through the first three years of the Plan.

The Fishery

Beginning in May 1994, major changes occurred in the data collection procedures for commercial fisheries in the Northeast. As noted in the **Introduction**, these changes have compromised the ability to assess the fishery on the spatial scale used in previous assessments. The three major US sea scallop grounds include the Gulf of Maine, Georges Bank, and the Mid-Atlantic. In SAW-20, the Georges Bank stocks were assessed as three subunits comprising the Great South Channel (GSC), Southeast Part (SEP), and the Northern Edge and Peak (NEP); within the Mid-Atlantic region, two subunits, the New York Bight (NYB) and Delmarva (DMV), were assessed (Figure B1). Catches in the Gulf of Maine, Southern New England, and VA-NC were estimated, but no population or mortality estimates were provided.

In this assessment, the commercial catch databases were judged insufficient to partition catches as finely as before, but catches could be reliably allocated to the larger Georges Bank and Mid-Atlantic regions. Backlogs in the processing of databases resulted in varying levels of audit procedures. For the May 1994 - June 1996 period, there were three primary databases for description of the commercial fishery. These are the Dealer Logs (DL) of purchases from vessels, the Vessel Trip Reports (VTR) submitted by permit holders, and the Days-at-Sea (DAS) call-in data.

The Dealer Logs (DL) are required for each primary purchase of scallops by dealers from fishermen and are considered to be a complete summary of landings. The VTR data comprise a subset of the Dealer Logs (DL) owing to the problems of incomplete records and as yet unresolved audit problems. It is important to point out that the geographic information of fishing (statistical area) and fishing effort (crew size and days at sea) are only provided by VTR, although these fields are frequently missing in the databases available to date. For assessment purposes, a "trip" is defined as period of fishing in a single statistical area by a single vessel. Thus, an individual vessel that spent 14 days at sea and fished in Statistical Area 522 for 10 days and in Statistical Area 525 for 4 days would count as two "trips".

A comparison of the VTR and DL for the May-December 1994 period revealed 373 distinct permits which comprise 2,877 distinct trips in VTR versus 379 permits and 2,945 trips in DL. Results suggest a high percentage of compliance to the regulation, but the identification of unique trips is difficult. For the May-December 1994 comparison, less than 400 distinct trips had a one-to-one correspondence between the VTR and DL databases.

A preliminary evaluation was performed relative to the utility of a Days-at-Sea (DAS) database for assessment purposes. The DAS database is derived from telephone call-ins of vessel captains to NMFS. Although this database is collected for enforcement rather than assessment purposes, it was considered to be an interim substitute for total effort information until the VTR data are fully audited. As in the DL data, geographic information on fishing area is unknown in DAS data and, thus, VTR data were required in order to partition effort into regions. Unfortunately, the VTR and DAS databases cannot be directly linked at present. The SARC recommended further investigation towards resolving these issues.

The following text table summarizes the status of the three major databases at the time this report was prepared.

Database	Time Period	Audit Status
Weightout Database	1982 to April 1994	Fully audited.
Vessel Trip Reports (VTR)	May-December 1994	Fully audited by Regional Office and NEFSC with Stages 1-3 and side-by-side audits. A very small, but unknown fraction of 1994 may not have been received or entered by October 1996.
	January-May 1995	Stages 1-3 audit complete, but no side-by-side comparisons. Keypunched by Regional Office.
	June-October, December 1995	60% of records pre-audited by Regional Office prior to keypunching by contractor. No additional audits have been performed.
	November 1995	Not available at time of assessment. Data were at keypunch contractor.
	All 1995	A very small fraction (< 0.5%) of the VTRs have not been submitted. Fishermen have until April 1997 to return VTRs for fishing activities in 1995. The effect of the small number of returns and low levels of catch are thought to be minimal.
	January-June 1996	Records were keypunched by Regional Office, but no audits have been performed.
Dealer Logs (DL)	1994, 1995, and January-June 1996	Data keypunched and audited by port agents and Regional Office. Data considered to be accurate census of legal landings, but cannot be used to allocate landings to subregions.
Days-At-Sea call-in database (DAS)	April 1994 - June 1996	Confidential data received by Regional Office. Data were used to estimate total days at sea by resource area because not all of the unaudited VTR data included days at sea as part of report.

Monthly landings on Georges Bank and in the Mid-Atlantic were estimated by partitioning the State-specific DLs by the fraction of VTR landings in the same cell ascribed to each region. In other words, the monthly landings by State (i.e., ports) were subdivided into regions based on the landings patterns in the VTR database. The general catch estimation methodology for each gear type was:

$$\text{Landings}_{\text{Region, Month}} = \sum_{\text{State}} (\text{DL Landings}_{\text{State, Month}}) \cdot (\text{Proportion in VTR}_{\text{State, Month, Region}})$$

VTR effort data could not be analyzed due to incomplete data fields on days at sea. It was felt that the number of trips by statistical area and catches by gear type could not be reliably estimated for 1994-1996 until the databases had been fully audited.

Commercial Landings and Effort

Historical US and Canadian landings from NAFO Subareas 5-6 are given in Table B1 and Figure B2. Total commercial landings (US and Canada) peaked at 26,671 mt (meats) in 1978. US and Canadian landings declined to 9,781 mt in 1984, increased to a near record-high of 22,831 mt in 1991, but fell to 9,822 mt in 1995. Total US landings peaked in 1990 when 17,174 mt of sea scallop meat were landed. Total US sea scallop landings in 1995 remained at about 8,000 mt, a level comparable to values in 1993 and 1994. Average US landings in the 1993-1995 period (7,944 mt) were less than half of the average for the previous 3-year period. Through June 1996, 3,647 mt were landed suggesting a lower projected catch in 1996 than in 1995. Recent declines in Canadian landings in NAFO Subarea 5 have been more severe, but this fishery is managed under quota restrictions.

Dredges and otter trawls are the primary gear types in the sea scallop fisheries. The vessels using dredges have accounted for more than 98% of the landings since 1964 (Table B2). In the Mid-Atlantic, where otter trawls historically have landed a much larger fraction of the catch, about 12% of the 1995 landings came from otter trawls.

Among the scallop dredge vessels, tonnage classes 3 (51-151 GRT) and 4 (151-500 GRT) have landed more than 95% of the scallops since 1980. The percentage of landings by tonnage class 3 decreased generally over the past three decades while the percentage of landings by tonnage class 4 increased (see Table D9 of NEFSC 1995). Landings by vessel tonnage classes were not computed for 1994-1996.

The proportion of total dredge trips between the Mid-Atlantic and Georges Bank regions has fluctuated historically (Figure B3). Before 1994, these fluctuations were driven primarily by the availability of strong year classes. Since 1994, the changes have been induced by both the presence of strong year classes in the Mid-Atlantic and the closure of fishing grounds on Georges Bank. Since 1994, the proportion of vessel trips has been 3-5 times greater in the Mid-Atlantic than on Georges Bank.

Georges Bank

US landings from Georges Bank dropped dramatically in 1994 as a result of several years of poor recruitment and a drop in effort as vessel effort was redirected toward moderately strong year classes in the Mid-Atlantic region. Areas I and II in the Great South Channel (GSC) and Northern Edge and Peak (NEP) regions, respectively, were closed to scallop vessels in December 1994, but probably had minimal effect on the landings in 1994. Between 1990 and 1994, landings dropped by 90% on Georges Bank. Landings in 1995 were about the same as in 1994, but the closed areas undoubtedly reduced the harvest (Table B3).

Canadian landings on Georges Bank have historically occurred from the region east of the boundary line established by the International Court of Justice. Current Canadian landings on Georges Bank are controlled by quota regulations. Assessment results in 1994 identified the low levels of incoming recruitment (Robert *et al.* 1994) and the 1995 quota of about 2,000 mt was set at 40% of the previous year's value. The 1996 quota was set at 3,000 mt (Robert, DFO, Halifax, pers. comm; Robert *et al.* 1996).

Total US and Canadian landings from Georges Bank in 1995 of 2,991 mt were the lowest in the 1957-1995 period and less than 65% of the previous all-time minimum value (Table B3)

Mid-Atlantic

Landings in the Mid-Atlantic region averaged about 6,000 mt in 1994 and 1995 (Table B2). These levels were about twice as high as 1993 landings and were primarily driven by the strong 1990 and 1991 year classes. Catches through the first half of 1996 were nearly 3,000 mt. It was not possible to partition landings by subarea within the Mid-Atlantic as was done for SAW-20.

Discards

The NEFSC sea sampling program for sea scallops began in 1992. Observers were trained by the NEFSC and were aboard on vessel trips selected at random. The observers collected information on the weight of landings and shell heights of discarded and kept scallops from the watched tows selected at random. Table B4 lists the number of trips and shells collected by observers from 1992 to June 1996.

A two-stage sampling technique (Cochran 1977) was used to estimate the discard-to-kept ratios of the two regions (Tables B5 and B6). Discard rates of scallops appear to be low and have decreased significantly in 1995 and 1996. Reductions are probably attributable to changes in ring size, the absence of meat count regulations, and overall reductions in catch. On Georges Bank, the ratio ranged from 0.3% in 1994 to 9.4% in 1996. In the Mid-Atlantic region, the ratio ranged from 0.5% in 1993 to 14.2% in 1994.

The shell height frequency distributions of discarded and kept scallops are shown in Figure B4. The distributions of discarded scallops were generally dominated by the scallops less than 80 mm shell height. Small sample size (59 shells) may be responsible for the apparent anomaly in 1994. Discard estimates for Georges Bank in 1996 also appear to be anomalous and will be investigated further.

At SAW-20, the low number of trips in the scallop sea sampling program was noted. The number of sampled trips on Georges Bank decreased from 10 trips in 1992-1993 to four trips in 1994-1996, but retained an average of 10 trips in the Mid-Atlantic region. Area closures (see Appendix I for details) probably contributed to the reduction in sea sampling effort on Georges Bank.

No direct estimates of discard mortality are available. Anecdotal information from fishermen and scientists suggest potentially high rates due to crushing of small scallops and freezing in winter.

Since discard estimates were only available for 1992 - June 1996, they were not incorporated into the estimates of stock abundance and fishing mortality.

Commercial Shell Height Frequency Distributions

The NEFSC port (dock-side) sampling program has provided the historical database for the commercial landings. Sampling protocols request a sample of about 200 shells from the last tow of the trip. Numbers of sampled trips and shells used to construct commercial shell height frequency distributions are summarized in Table B7. Since 1994, the port sampling program was reduced in both regions and almost ceased in 1995 on Georges Bank.

At SAW-20, the samples over year, quarter, and 10-minute squares of latitude and longitude for 1991-1993 were reviewed. Visual comparison of locations where the samples were collected suggested a spatial pattern comparable to overall landings. However, this comparison was not continued because of insufficient sampling effort in 1994-1996.

Comparisons of the shell height frequency distributions collected from sea and port sampling programs for 1992-1996 showed close agreement on Georges Bank, except in 1995 (Figure B5). In the Mid-Atlantic region, sea sampling suggested a slightly higher proportion of scallops less than 85 mm for 1992-1995; in 1996, the pattern was reversed (Figure B6). Differences between median shell heights for the sea and port samples however, were small in all years except 1996.

In view of the reduced port sampling program since 1994, the sea sample shell height distributions were pooled with the port samples for 1992-1996. The resultant shell height frequency distributions from 1992 to 1996 (Figures B7 and B8) were the average of trip-specific, shell height frequency distributions collected from sea and port sampling programs obtained by standardizing the sample size of each sea sampling trip sample to 200 shells. Reductions in port and sea sampling could reduce the precision and accuracy of data for stock assessment (e.g., catch in number of scallops, mean meat weight, size-specific vulnerability and selectivity, etc.). One of the obvious problems is that the shell height frequency distributions cannot be investigated on a sub-regional (e.g., Northern Edge and Peak) basis.

Even under these severe limitations, the shell height frequency distributions in the two regions adequately characterized the progression of year-class strength. For instance, the shell height frequency distribution on Georges Bank in 1995 (Figure B7) indicated the absence of small fully-recruited scallops followed by the low survey abundance indices of pre-recruits in 1993 (1990 year class) and 1994 (1991 year class). In the Mid-Atlantic region, the smallest modal size at 80 mm in the 1994 shell height frequency distribution (Figure B8) reflected the strong 1990 year class which appeared as pre-recruits in the 1993 survey followed by weak 1988 and 1989 year classes.

Stock Abundance and Biomass Indices

Sea scallop research surveys have been conducted by the NEFSC since 1975 (annually since 1977) to monitor and assess abundance, population composition, and recruitment of the offshore sea scallop resources. The survey design and estimation procedures are described by Serchuk and Wigley (1989), Wigley and Serchuk (1996), Richards (1996), and Lai and Hendrickson (1997). A map of the survey strata is provided in Figure B9; the sub-region definitions are depicted in Figure B10. Due to gear problems on the R/V *Albatross IV*, the Canadian portion of Georges Bank was not completely sampled in 1996.

Results of the 1996 survey indicate that the indices of relative abundance and biomass in the Mid-Atlantic region decreased substantially from the relatively high levels observed between 1993 and 1995. In the US portion of Georges Bank, the indices of relative abundance and biomass increased substantially from the 1995 value. The 1996 survey results are summarized below; additional details may be found in Lai and Hendrickson (1997). Analyses of the effects of open and closed areas on Georges Bank are presented in the section on "Effects of Closed Areas".

US Portion of Georges Bank

In the US portion of Georges Bank in 1996, the indices of relative abundance and biomass were at median levels after having declined to their lowest values in 1993 for the post-1984 time series (Table B8). The increases were primarily due to increases in recruit abundance from 25.1 scallops/tow in 1995 to 69.2 scallops/tow in 1996. The increase in recruits was attributed to the moderately high number of pre-recruits observed in 1995. The relative abundance of pre-recruits in 1996 was 67.6 scallops/tow, a decrease of 19% from 1995 (82.4 scallops/ tow).

In the Great South Channel area of Georges Bank, abundance and biomass of recruits in 1996 were 87.3 scallops/tow and 1.26 kg/tow, respectively. These levels were more than 2 times those in 1995 and were the third highest in the time series (Table B8). The increase in recruited scallops is due to the moderate 1992 year class which represented the pre-recruits in 1995. The number of pre-recruit scallops/ tow decreased 50% from that in 1995.

In the Southeast Part, abundance and biomass in 1996 were about average (Table B8). The abundance of pre-recruits in 1996 increased 49% from the value in 1995, while recruits decreased slightly. The abundance of total scallops in 1996 increased 20% from the value in 1995.

On the US portion of the Northern Edge and Peak in 1996, abundance and biomass for total scallops, pre-recruits, and recruits increased to the second highest level in the time series (Table B8). Pre-recruits (likely the 1993 year class) comprised 55% by number of the resource in this area..

Mid-Atlantic

In the Mid-Atlantic region, the relative abundance of total scallops increased between 1992 and 1995 but decreased substantially from 1995 to 1996 (Table B9). The number of scallops per tow decreased 67% from 170 in 1995 to 56.9 in 1996. The total weight per tow in 1996 was 0.57 kg, 49% lower than the 1995 value.

In the New York Bight area, the 1996 indices of relative abundance and biomass decreased substantially from 1995. The number of scallops per tow decreased 66% from 163.8 in 1995 to 55.2 in 1996 (Table B9). The mean weight per tow was 0.56 kg in 1996, a decrease of 51% from 1.15 kg in 1995. In 1996, the indices of relative abundance for pre-recruits and recruits also decreased. The relative abundance of pre-recruits in 1996 (5.7 scallops/tow) was less than 10% of the level in 1995 (57.7 scallops/tow). The relative abundance of recruits (49.5 scallops/tow) was 47% of the 1995 level (106.1 scallops/tow). The 1996 pre-recuit biomass index (0.55 kg/tow) was 57% of that in 1995 (0.97 kg/tow).

In the Delmarva area, the abundance of sea scallops decreased sharply from 1993 to 1996 (Table B9). The number of scallops per tow decreased from 204.7 in 1995 to 66.1 in 1996. In 1996, the abundance of pre-recruits was only 24% and recruits 41% of that in 1995.

In the Virginia - North Carolina area, the number of scallops/tow in 1996 was 46% and weight per tow 31% of that in 1995 (Table B9). In 1996, the abundance of pre-recruit decreased 46 % from the 1995 value. Abundance of recruits decreased precipitously from 11.7 scallops/tow in 1995 to 1.0 scallops/tow in 1996, a decrease of 92%.

Effect of Management Measures

Amendment 4 of the Atlantic Sea Scallop FMP was approved in November 1993, but implementation was delayed until March 1, 1994. A chronological summary of the major management measures that have been implemented and are currently planned under the provisions of Amendment 4 is depicted in Figure B11. Key regulations include minimum meat counts per pound, minimum shell heights, the planned schedule of days at sea reductions, minimum ring sizes, maximum crew sizes, and restrictions on gear configuration. The timeline indicates the starting and stopping points of various regulations. In December 1994, two fishing areas on Georges Bank and one in Southern New England were closed to all fishing in response to the collapse of groundfish stocks. These areas remain closed. Given the diversity of measures, variations in their timing, and potential confounding of effects, any changes in fishing mortality effected by Amendment 4 will be difficult to attribute to any single provision.

At SAW-20, it was noted that *"The variation in the spatial dynamics of the fleet components could become increasingly important as the provisions of Amendment 4 take effect and could be an important explanatory variable in statistical models for effort standardization. Spatial analysis of fleet dynamics should be an important part of future scallop assessment."* The present assessment reinforces these same conclusions. Abilities to conduct detailed spatial analyses, however, will continue to be compromised until the VTR databases have been fully audited and linked with the Dealer Logs.

Unfortunately, the present status of the VTR and DL databases does not permit a thorough investigation of the effects of the new management measures. Present investigations were made on 1) the comparison of shell height frequency distributions between survey catch and commercial landings and 2) the comparison of abundance indices and shell height frequency distributions in the post-stratified closed and open areas.

Vulnerability

An exploratory analysis of the population vulnerable to the fishery was developed to investigate the effect of changing ring size over years. Assume that the abundance indices in the h^{th} shell height category (n_h) are proportional to its corresponding population size (N_h) and the proportionality is constant over all size categories. That is, $n_h = a \cdot N_h$. Let s_h be the size-specific vulnerability of harvested scallops; then $C_h = s_h \cdot n_h$. Assume that s_h is governed by a logistic curve:

$$s_h = \frac{1}{1+\exp(\alpha+\beta h)} \tag{1}$$

The proportion of landed scallops in the h^{th} size category can be theoretically calculated by:

$$p_h = \frac{C_h}{\sum C_h} = \frac{s_h n_h}{\sum s_h n_h} \tag{2}$$

Let p'_h be the observed proportion of landed scallops in the h^{th} size category, which is measured with log-normally distributed random error (e_h); i.e.,

$$p'_h = p_h + \varepsilon_h \tag{3}$$

The parameters a and b in the logistic vulnerability curve are estimated by nonlinear least squares. The derived parameters L_{25}, L_{50}, and L_{75}, which represent the lengths at which 25, 50, and 75% of the population, respectively, are vulnerable to the fishery, were computed from the estimates of a and b.

The model performance is evaluated based on the predicted and observed shell height frequency distributions for the George Bank and Mid-Atlantic regions (Figures B12 and B13). In spite of some discrepancies, the data fit the model reasonably well for the two regions. The estimated vulnerability curves in 1990-1996 are shown in Figures B14 and B15. The shift of vulnerability curves toward large-sized scallops in 1995-1996 were obvious on Georges Bank (Figure B15). Vulnerability patterns in the open areas in 1995 (Figure B15), however, were indistinguishable from those in previous years. The apparent increase in size at median vulnerability in 1996 in the open area may be due to the low recruitment rates in recent years on Georges Bank. When the survey-based size compositions for both open and closed areas are considered for 1995 and 1996, major changes in vulnerability are evident. These changes are most likely attributed to the conservation of the population (and resultant growth rates) in the closed areas.

The shell height at median vulnerability (L_{50}) remained relatively stable between 1986 and 1994 on Georges Bank (Figure B16). Meat count restrictions of 35 meats per pound may have contributed to this stable pattern. The increase in median vulnerability in 1995 is probably attributable to recruitment indices in 1993-1994 (Figure B16). An increase in the abundance index of recruited scallops in 1995 and reductions in fishing effort due to the closed areas indicated that more fully recruited, small-sized scallops were available to the fishery in 1996 and, thus, decreased L_{25}, L_{50}, and L_{75} from the levels of 1995.

In contrast to Georges Bank, small-sized scallops were more vulnerable in 1996 in the Mid-Atlantic region (Figure B14). Vulnerability patterns for the 1994 and 1995 fisheries were similar to those observed in other years. The long-term pattern of vulnerability appears to be relatively stable in the Mid-Atlantic region (Figure B17). Decreases in L_{25}, L_{50}, and L_{75} in 1996 (Figure B17) may be due to the entry of the 1992 year class (Table B9) and the near absence of the 1990 and 1991 year classes.

It is clear that the vulnerability of scallops is governed by various sources of management measures and year-class strength. Gear selectivity and other technological control measures can interact to produce actual size compositions of the catch that differ from the predictions of the control studies (DuPaul and Kirkley 1995) for the selectivity of various ring sizes.

Effects of Closed Areas

A significant fraction of the sea scallop fishing grounds (Figure B18) were closed in December 1994 in an attempt to protect depleted groundfish species. At the time of the August 1996 NEFSC scallop survey, populations in the closed areas had been protected from fishing mortality for about 20 months. To assess the effect of the closures, survey strata (see Figure B10) were post-stratified into open and closed areas, and size-specific means and variances of numbers and weight per tow were re-computed using the standard methodology for stratified random samples (Cochran 1977). GIS methods were used to determine whether the samples were within or outside the closed area for each of the original NEFSC survey strata. Detailed maps of the stations within and outside the closed areas for 1991-1996 are presented in Appendix II.

The general estimator for size-specific post-stratified means was

$$\bar{y}_{st} = \sum_{j \in \{st\}} \frac{A_j}{A} \sum_{i \in \{st\}}^{n_j} \sum_{h=h_{min}}^{h_{max}} \frac{y_{j,i,h}}{n_j} \qquad (4)$$

where

A_j = area in stratum j,
A = sum of all areas j within stratum of interest, e.g., open vs closed,
{st} = set of all stations within the stratum of interest,
n_j = number of stations in stratum j,
h_{min}, h_{max} = minimum and maximum shell height range,
$y_{j,i,h}$ = number or weight of scallops of shell height h collected at station i within stratum j.

The variance of the stratified mean was:

$$\text{var}(\bar{y}_{st}) = \sum_{j \in \{st\}} \frac{A_j}{A^2} \left(\frac{s_j^2}{n_j} \right) \qquad (5)$$

where s_j^2 = the sample variance for stratum j.

Estimated weight per tow was computed by applying the weight - shell height regression to the observed shell height frequency and summing over shell-height intervals.

Post stratification can result in missing or reduced numbers of observations in the new strata. For the period 1990-1996, the resulting numbers of stations in the overall areas appear to be stable with an average of 121 and 69 samples in the open and closed areas, respectively (Tables B19 and B20). Equations 4 and 5 were applied to the meat weight of scallops per tow (kg) ≤ 70 mm and > 70 mm (Figure B19).

The average weight per tow of pre-recruits was generally higher in the closed areas than in the open areas for the period 1990-1996, but confidence intervals overlapped in all years except 1993. Values for 1996 were about three times greater in the closed areas (Figure B19). The closed:open ratio of recruits is indicative primarily of changes in recruitment since these size classes would have been subjected to little fishing mortality in either the open or closed areas. In contrast, the closed:open ratio for scallops ≥ 70 mm is primarily determined by differences in mortality. In 1996, the weight per tow in the closed areas was 2.7 times greater than in the open areas (Figure B19). Moreover, the closed:open ratio for average weights per tow of both recruits (≤ 70 mm) and full recruits (> 70 mm) in the previous year (1995) was equal to 1.0 Therefore, the increase in fully-recruited scallops in the closed areas in 1996 was unaffected by differences in the 1995 abundance of pre-recruit scallops ≤ 70 mm in the closed and open areas. Changes in overall numbers per tow of pre-recruit and recruited scallops are depicted in Figure B20. Variability in the number per tow tends to be greater than for weight per tow, but the same general pattern is evident.

Further insights into the changes in size composition between open and closed areas are found in Figure B21. The 1992 year class observed in 1995 was depleted substantially in the open areas, but was relatively untouched in the closed areas. To test whether the differences in the size compositions between the open and closed areas could be due to the absence of fishing mortality, the von Bertalanffy growth equation was used to project the expected size composition and change in weight between age size classes. The projected size composition in the closed areas for 1996 was obtained by applying the von Bertalanffy equation to the 1995 size composition and smoothing with a 3-point moving average. The 3-point moving average was used because scallops are only measured on a 5-mm interval, a scale too broad for the varying growth rates of some size classes.

The observed size composition for 1996 in the closed areas agreed very well with the projection (Figure B22). The maximum size in the von Bertalanffy equation was set at 162 mm as this was the observed value in 1995 and 1996. Historically, the largest scallop observed in the NEFSC scallop survey was 177 mm. The von Bertalanffy equation and shell height - weight regression could also be used to predict the expected increase in weight of adjacent age groups (i.e., the von Bertalanffy equation was used to define appropriate length intervals corresponding to a 1-year time step). A comparison of the observed and predicted weight ratios of length classes in the open and closed areas is given in Table B10. The predicted weight gains in the closed areas were slightly lower than the observed. In contrast, the observed weight ratios in the open areas were only about one third of the predicted.

Overall, the results demonstrate the rapid weight gains possible in unfished populations. Results suggest a possible biological foundation for future management measures based on selective closures to protect regions abundant with undersized scallops.

Estimates of Stock Size and Fishing Mortality Rate

When the modified DeLury model (Conser 1991, 1995) was first applied to sea scallops in SAW-14 (Anon. 1992), several problems were identified, particularly with respect to alternative assumptions about gear selectivity in research surveys. Many of these issues were addressed at SAW-20 (NEFSC 1995). A new model for estimating gear selectivity was developed and an alternative methodology for estimating recruits and full recruits was presented. At SAW-20, the modified DeLury model was applied to five separate resource areas for which sufficient data on landings, research surveys, and size compositions were available. These areas were the Great South Channel, Southeast Part, and Northern Edge and Peak on Georges Bank, and the New York Bight and Delmarva in the Mid-Atlantic. At the time of SAW-20, data on fisheries landings for the first half of 1994 were not available. For that reason, the DeLury model was applied on a calendar-year basis in which the catches were assumed to be removed at the midpoint of the calendar year and the survey was representative of the average biomass during the calendar year.

For SAW-23, data limitations mandated the development of pooled estimates for the Georges Bank and Mid-Atlantic regions. In addition, the model was applied to survey years because catch data for the first half of 1996 were available. This results in a somewhat more realistic application of the model because the survey was taken to represent a point estimate of abundance. The innovations developed at SAW-20 for the application of the DeLury model are briefly reviewed in the sections on "Selectivity of Lined and Unlined Dredges used in Research Surveys" and "Estimation of Abundance Indices of Recruited and Fully-Recruited Stock Sizes". The DeLury model theory is presented in the section on "Application of Modified DeLury Method" and results are found in the section on "Estimates of Abundance and Fishing Mortality Rates". Full details on the model results may be found in Appendices III and IV.

Selectivity of Lined and Unlined Dredges Used in Research Surveys

Since 1979, the NEFSC research vessel survey for sea scallops has used a 2.44-m (8-ft) wide scallop dredge equipped with 5.1-cm (2-in.) rings and a 3.8-cm (1.5-in.) polypropylene mesh liner and towed for 15 minutes at 6.5 km/hr (3.5 knots) with a 3:1 wire scope (Serchuk and Smolowitz 1980). This gear has been used as a standard because it is more efficient in retaining pre-recruited scallops (≤ 70 mm shell height) than the unlined dredge used in 1975 and 1978 (3.05-m or 10-ft wide). However, Serchuk and Smolowitz (1980), as well as Jamieson and Lundy (1979) and Worms and Lanteigne (1986), reported that the presence of the liner results in lower catchability for scallops > 75 mm in shell height.

The selectivities of lined and unlined dredges were investigated at SAW-20 using the maximum likelihood estimation method to the composite ratio of two selectivity functions for the unlined and lined dredges. The resultant selectivity curve for the unlined dredge is:

$$\hat{q}_h^{'} = \frac{1}{1 + \exp(3.7992 - 0.0768\,h)} \tag{6}$$

and that for the lined dredge is:

$$\hat{q}_h = \frac{0.7148 \exp[(0.9180)(0.7148)(x - 106.3091)] + \exp[0.9180(x - 106.3091)]}{\exp[(0.9180)(0.7148)(x - 106.3091)] + \exp[0.9180(x - 106.3091)]} \tag{7}$$

where x = 160 - h. Figure B23 shows the input data, estimated selectivity curves, and diagnosis of fitting data to the model. The selectivity of the lined dredge, together with the effect of growth (shown in the next section) and fishery selectivity was applied to the survey shell height frequency distributions to reconstruct the indices for recruited and fully recruited scallops as input indices for the DeLury model.

<u>Estimation of Abundance Indices of Recruited and Fully-Recruited Stock Sizes</u>

A new procedure was developed at SAW-20 to estimate the recruited and fully recruited stocks based on the fishery selectivity and von Bertalanffy growth model. For the purposes of the current assessment, the methodology is termed the "Selectivity Method". A diagrammatic representation of the method is given in Figure B24. Basically, the composite size frequency distribution of the survey at time t can be partitioned into three groups: 1) fully vulnerable to the fishery at time t, i.e., n_t, 2) invulnerable to the fishery at time t, but vulnerable by time t+1, i.e., r_t, and 3) invulnerable to the fishery at time t and t+1, i.e., b_t:

$$\sum_{h=h_{min}}^{h_{max}} N_h = n_t + r_t + b_t \tag{8}$$

where

- N_L = number of animals in sample at size h at time t,
- n_t = fully recruited portion of the sample at time t,
- r_t = recruit portion of the sample at time t,
- b_t = portion of the sample that are neither fully recruited nor recruits,
- h_{min} = minimum size in the sample,
- h_{max} = maximum size in the sample.

The number of full recruits is derived by applying a commercial selectivity function s(h) to the composite size distribution. The function s(h), developed by consensus at SAW-14 (NEFSC 1992), describes the expected probability of landing a scallop of shell height h, given capture, as a time-invariant, piecewise-linear function:

$$s(h) = \begin{cases} 0.0 & if\, h < h_{minsel} \\ \left(\dfrac{h - h_{minsel}}{h_{fullsel} - h_{minsel}} \right) & if\, h_{minsel} < h < h_{fullsel} \\ 1.0 & if\, h < h_{fullsel} \end{cases} \tag{9}$$

where

- h_{minsel} = smallest animal selected by fishery = 65 mm,
- $h_{fullsel}$ = first size that is fully selected = 88 mm.

Multiplying the above equation by the composite size frequency gives:

$$n_t = \sum_{h=h_{min}}^{h_{max}} N_h s(h) \tag{10}$$

Estimation of the number of recruits also involves the joint product of the fraction invulnerable to the fishery at time t, i.e., [1.0-s(h)] and the expected fraction vulnerable at time t+1, i.e., s(h+Δh):

$$r_t = \sum_{h=h_{min}}^{h_{max}} N_h [1 - s(h)] s(h + \Delta h_h) \tag{11}$$

The term s(h+Δh) depends on the growth increment Δh_h which is defined as:

$$\Delta h_h = (H_\infty - h)(1 - e^{-K}) \tag{12}$$

where H_∞ and K are von Bertalanffy growth parameters specific to the Georges Bank and Mid-Atlantic regions (Serchuk *et al.* 1979).

Region	H_∞	K
Georges Bank	153.46	0.3374
Mid-Atlantic	151.84	0.2297

The group of scallops that are either too small to grow into the vulnerable size group or which fail to become fully vulnerable can be estimated as the sum of two components:

$$
\begin{aligned}
b_t &= \sum_{h=h_{minsel}}^{h_{fullsel}-1} N_h(1-s(h))[1-s(h+\Delta h_h)] \\
&+ \sum_{h=h_{min}}^{h_{minsel}-1} N_h[1-(1-s(h))s(h+\Delta h_h)] \\
&= \sum_{h=h_{min}}^{h_{max}} N_h(1-s(h))[1-s(h+\Delta h_h)]
\end{aligned} \tag{13}
$$

The Selectivity Method was applied to the adjusted annual survey size frequency compositions to estimate recruited and fully-recruited stocks (Table B15) in each resource area. Annual landings, mean weights, and catch in number by half-year intervals are also provided in Table B15.

Application of Modified DeLury Method

The modified DeLury model (Conser 1991, 1995) was used to estimate stock sizes in number and biomass and fishing mortality rates for sea scallops on Georges Bank and in the Mid-Atlantic. In contrast to the model applied at SAW-20, a survey year rather than the calendar year was used as the basis for estimating abundance and mortality. A survey year (i.e., July 1 - June 30) application could not be used in the previous assessment because the January-June 1994 catch data were unavailable.

In summary, the model is based on the assumptions described in the following equations:

$$
\begin{aligned}
n_t &= q_n N_t \\
r_t &= q_r R_t
\end{aligned} \tag{14}
$$

and

$$N_t = (N_{t-1} + R_{t-1})\exp(-M) - C_{t-1}\exp[(t_c - t_s - 1)M] \tag{15}$$

where

N_t is the fully recruited stock size in number of the population at year t,
R_t is the recruited stock size in number of the population at year t,
C_t is the catch in number from the start of year t-1 to the start of year t,
M is the instantaneous natural mortality rate,
t_c is the point during the calendar year when the catch is taken,
t_s is the point during the calendar year when the research survey is carried out, for which $0 < t_s < t_c < 1$,
n_t is the survey abundance index of the fully recruited stock at year t,
r_t is the survey abundance index of the recruited stock at year t.

Substituting Equation 14 into 15 and adding a random process error (ϵ_t) to obtain the relationship of the abundance indices of the fully-recruited and recruited stocks gives:

$$
\begin{aligned}
n_t = \{&(n_{t-1} + s_r r_{t-1})\exp(-M) - \\
&q_n C_{t-1}\exp[(t_c - t_s - 1)M]\}\exp(\varepsilon_t)
\end{aligned} \tag{16}
$$

where $s_r = q_n / q_r$. Let n'_t and r'_t be the observations of population abundance indices n_t and r_t, respectively, then:

$$
\begin{aligned}
n'_t &= n_t \exp(\eta_t) \\
r'_t &= r_t \exp(\delta_t)
\end{aligned} \tag{17}
$$

where δ_t and η_t are the random measurement errors.

The parameters $\underline{\Theta}' = \{(n_t| t=1,...T), (r_t| t=1,...T-1), q_n\}$ are estimated by a method of weighted least squares:

$$SS(\underline{\Theta}) = \lambda_\epsilon \sum_{t=2}^{T} \epsilon_t^2 + \lambda_\eta \sum_{t=1}^{T} \eta_t^2 + \lambda_\delta \sum_{t=1}^{T-1} \delta_t^2 \tag{18}$$

where λ_ϵ, λ_η, and λ_δ are the weighting factors for the process error associated with the system Equation 16 and the measurement errors associated with the observed values (Equation 17). The weighting factors were normalized so that $\lambda_\epsilon + \lambda_\eta + \lambda_\delta = 1$. The coefficient s_r was set equal to 1.0. The catches in number for all years are input into the model without the assumed structure of random error.

Estimation of mortality rates

The recruited and fully-recruited stock sizes are estimated as:

$$\hat{N}_t = \hat{n}_t / \hat{q}_n$$
$$\hat{R}_t = s_r \hat{r}_t / \hat{q}_r \tag{19}$$

The total mortality and fishing mortality rates in year t for the entire population are calculated respectively by:

$$Z_{R+N,t} = -\ln\left(\frac{\hat{N}_{t+1}}{\hat{N}_t + \hat{R}_t}\right)$$
$$F_{R+N,t} = Z_{R+N,t} - M \tag{20}$$

The fishing mortality rates for the recruited ($F_{R,t}$) and fully-recruited ($F_{N,t}$) stocks are calculated by applying the average partial recruitment $\bar{p}_{R,t}$ of the recruited stock into the commercial fishery over the course of year t, i.e.,

$$F_{N,t} = \frac{F_{R+N,t}(\hat{R}_t + \hat{N}_t)}{\bar{p}_{R,t}\hat{R}_t}$$
$$F_{R,t} = \bar{p}_{R,t} F_{N,t} \tag{21}$$

The partitioning of F into recruit and full-recruit components is totally dependent on the PR parameter. In general, this parameter is difficult to estimate and is likely to vary among years. Therefore, estimates of stage-specific mortality rates are highly uncertain and should be carefully examined for realism.

Estimates of Abundance and Fishing Mortality Rates

It is important to reiterate that the DeLury model was applied on a survey-year basis in this assessment. The catches referred to as C_t in this document represent landings during July-December in year t and January-June in year t+1. In addition, the assessment regions are summarized as Georges Bank and the Mid-Atlantic. The SAW-20 document considered three sub-regions on Georges Bank and two in the Mid-Atlantic.

Fishing mortality rates and recruited and fully-recruited stock sizes for sea scallops in the Georges Bank and Mid-Atlantic regions were estimated from the modified DeLury model using the data in Table B11. The complete outputs from the final runs for the populations on Georges Bank and in the Mid-Atlantic were given, respectively, in Appendices III and IV. Figures B25 and B26 show the observed survey indices and their fitted values, catches, and the standardized residuals for the measurement and process errors.

The standardized residuals of predicted recruited and calculated fully-recruited survey indices have similar trends with a 1-year lag in the two regions (Figures B25 and B26). This pattern is to be expected in the DeLury model when the level of fishing mortality is high and catch is nearly equal to or exceeds the number of full recruits.

Initial runs of the model for Georges Bank suggested that the recruited index for 1989 was an apparent outlier and contributed about 66% of the sum of squares in the model fitting (Appendix III). When the model was rerun without the 1989 survey observations (Figure B25), none of the standardized residuals exceeded 2.0, suggesting no significant outlier.

In the Mid-Atlantic region, none of the standardized residuals exceeded 2.0, suggesting the absence of significant outlier (Figure B26). However, the standardized residuals of predicted recruited and calculated fully-recruited survey indices show a trend indicating that the indices might be under-estimated in the earlier years and over-estimated in the latter. A similar phenomenon was found in the New York Bight sub-region in the report to SAW-20. Because the landings and resource of sea scallops in the Mid-Atlantic were predominated by the New York Bight sub-region, it can be expected that the sub-regional and combined region analyses showed a similar trend.

The abundance of fully-recruited sea scallops on Georges Bank decreased from peak levels in 1986, fell to the lowest levels in 1993-1995, but rebounded in 1996 (Figure B25). The abundance of recruited scallops also decreased since 1990. Catches have substantially declined since reaching the historic high in 1990, especially after the closed areas went into effect in 1994.

In the Mid-Atlantic region, fully-recruited abundance indices increased during 1994-1996 from a low level in 1993 (Figure B26). The fluctuating trend of fully-recruited abundance was similar to that of recruited abundance since 1986 with a 1-year lag. Catches in the Mid-Atlantic region reached a high in 1994 (at least for the available time series of data) and remained relatively high in the 1995-1996 survey year.

On Georges Bank, the fishing mortality rate of the entire population ($F = Z - M$) in the July 1995 - June 1996 survey year was 0.38 (Figure B27 and Appendix III). However, the ratio of catch in number to the fully-recruited population size (C/N) was greater than 1, indicating that the fisheries were highly dependent on the new recruits. In other words, it is a "recruitment fishery". The fishing mortality rates on the fully-recruited stocks (F_N) have substantially exceeded the overfishing definition (OD) over most of the assessment period. The value of F_N in 1995 was slightly less than the OD.

In the Mid-Atlantic region, the average fishing mortality on the entire population ($F = Z - M$) was 0.85 in the 1995-1996 survey year (Figure B28 and Appendix IV). The ratios of C/N during 1993-1995 exceeded 1.0 and were higher than the earlier years. The increased fishing effort in this region, probably due to the closed areas on Georges Bank in recent years, might post high fishing pressure on the population. The 1996 survey indicated the recruited and fully-recruited abundance indices were substantially reduced from the preceding year. The fishing mortality on the fully-recruited population (F_N) has exceeded OD since 1985. The concern about recruitment overfishing is evident.

The catchability coefficients q in the DeLury model represent a conversion factor between the survey indices and the true population size. As shown by Paloheimo and Dickie (1964), q can be expressed as the product of gear efficiency (i.e., probability of capture given encounter, $P_{C|E}$) and the ratio of total area occupied by the population (A) and the average area swept by the gear (a). Using the values of A and a given in Table B12 and the estimates of q in Appendices III and IV, the derived capture efficiencies for Georges Bank and the Mid-Atlantic Region were 2.7 and 1.7, respectively. Possible reasons for the apparent over-estimation of gear efficiency include underestimation of catch, heterogeneous spatial variability, or misspecification of the total population area. Each of these factors will be examined as part of an ongoing evaluation of the DeLury model by the NEFSC.

Relative Exploitation Rate

The DeLury model incorporates both survey and commercial catch data to estimate total mortality, but several related approaches are available. Critical requirements of the DeLury model include consistent estimates of population abundance and reliable estimates of total catch in numbers. If alternative estimators with less stringent requirements yield similar results, then the overall confidence in the DeLury-based estimates can be improved. Each of the alternative estimators is described below.

1. Relative exploitation rate is the general approach to relate total catch to an index of survey biomass. A form of relative exploitation rate was proposed by Sinclair (DFO, Canada, pers. comm.) and reviewed by Anon. (1995). The method is applied below to relative biomass estimates and landings. The basic catch equation for yield in weight C_W is written as:

$$C_W = F\overline{B} \tag{22}$$

where F is the instantaneous rate of fishing mortality and B is the average biomass. If survey estimates are available, the average biomass at time t can be estimated to within a arbitrary constant q as follows:

$$\overline{B}_{t+\Delta t/2} \approx q\left(\frac{I_W(t)+I_W(t+\Delta t)}{2}\right) \tag{23}$$

where $I_W(t)$ is the average biomass per tow in year t. Relative F can then be estimated as:

$$F_{REL} = \frac{F}{q} \approx C_W(t) \Big/ \left(\frac{I_W(t)+I_W(t+\Delta t)}{2}\right) \tag{24}$$

F_{REL} thus differs from true F only by the constant q. Equation 24 was applied to total landings in mt and survey biomass indices expressed as kg/tow.

2. If the survey estimates are scaled up by the ratio of the total survey area (A) to the average area covered by the scallop dredge (a), then Equation 24 can be expressed as a "swept-area estimate". The modified equation is:

$$F_{SWEPT} = F/q$$

$$\approx \frac{C_W(t)}{\left(P_{CIE}\dfrac{A}{a}\right)\left[\dfrac{I_W(t)+\left(\dfrac{w_n(t+\Delta t)}{w_n(t+\Delta t)+w_r(t+\Delta t)}\right)I_w(t+\Delta t)}{2}\right]} \tag{25}$$

where $C_W(t)$ = total catch in weight (mt), $w_n(t)$ = observed weight of full recruits per tow, $w_r(t)$ = observed weight of recruits, A = total area of the region A, a = average area swept by scallop dredge, and P_{CIE} = probability of capture given encounter (or gear efficiency). Equation 25 was applied for two levels of gear efficiency.

3. Equation 20 can be modified to simply use the survey estimates rather than the DeLury-based estimates of population size. Equation (20) becomes:

$$F_{Survey} = -\ln\left(\frac{n_{t+1}}{n_t + r_t}\right) \tag{26}$$

Results of the simple models agree closely with the DeLury model (Table B17). The trend in relative biomass agrees well with the DeLury-based estimates (Figure B29). Effects of the closed areas on Georges Bank were immediately evident, with relative exploitation showing a marked decline in survey years 1994 and 1995. In contrast, relative F levels in the Mid-Atlantic remained relatively steady from 1986-1990, increased sharply in 1994, and appear to have declined for the 1995 survey year.

Figures B30 and B31 demonstrate that 1) all of the estimators are strongly correlated in both areas and 2) the assumptions related to estimating catch in numbers rather than catch in weight have little effect on the estimate of mortality trends. Estimates based simply on the survey (Equation 26) appeared to have lower correlations with the other estimators. Inasmuch as the DeLury mortality estimators are unaffected by problems of estimating q, the SARC agreed to the use of Equation 20 for assessment purposes.

Biological Reference Points

Bootstrap estimates of average fishing mortality for the 1994 and 1995 survey years were compared to the $F_{5\%}$ threshold fishing mortality rate of 0.71. This 2-year period corresponds to the interval July 1994 - June 1996. Results shown in Figure B32 for the Mid-Atlantic show a 99% likelihood that the biological threshold has been exceeded the last two years. It appears that technological measures (DAS reductions, increased ring size, and reduced crew size) designed to reduce fishing mortality have not been sufficient to offset the redirection of fishing effort to the Mid-Atlantic Region. On Georges Bank (Figure B28), there is a 99% probability that the closed areas have reduced fishing mortality below the threshold level of 0.71. Conversely, there is only a 1% probability that the biological threshold has been exceeded on Georges Bank during July 1994 - June 1996.

The potential importance of closed areas as a management tool is clearly evident in the results of this assessment. Biomass increases in the closed areas are about 3-fold with less than 20 months of protection. Improvements in yield per recruit could more than offset the short-term reductions in landings. A "crop rotation" management system incorporating biological growth parameters and oceanographic factors to ensure re-seeding spat in harvested areas could have significant economic as well as biological benefits. Further work on this is recommended.

SARC Comments

The SARC expressed concern that the modified DeLury model underestimated stock size in relation to swept-area calculations and recommended that total mortality values from the survey be computed. The precision of the swept-area results, which rely on the assumption of a homogeneous distribution of scallops across the survey area rather than a more realistic aggregated distribution, was also questioned. As a result of these concerns, an evaluation of the relationships between exploitation estimators was conducted. The SARC concluded from this analysis that the modified DeLury model should be utilized since the fishing mortality rates from the model were highly correlated with the F_{REL} values. It was suggested that the discrepancy between the modified DeLury and swept-area stock size estimates may be attributable to an underestimation of catch in numbers, overestimation of surveyed area, or other factors. However, since the fishing mortality rate estimates rely on indices of relative abundance, they are unaffected by the problems inherent in specifying absolute levels.

After 20 months of closure, a significant increase (nearly 3-fold) in the 1996 post-stratified survey biomass index for scallops > 69 mm in length was evident for the closed areas on Georges Bank. However, the SARC also noted that a significant increase in biomass had also occurred in the closed area in 1991 prior to the prohibition of scallop fishing in these closed areas. As a result, the SARC advised extending the pre-closure time series to examine the effects of year-class abundance over a longer time period. The addition of the 1990 index did not resolve this issue, and it was suggested that pre-closure biomass increases are likely to be a carry-over effect from the large 1989 year class. However, since the 1989 survey did not include the US portion of the Northern Edge and Peak sub-region, this theory could not be tested without further extension of the pre-closure area time series. It was suggested that year-class effects may also be confounded by differential growth rates within the Georges Bank region.

An examination of the annual differences in vulnerability patterns in relation to the timing of implementing various management measures was also used to determine the effects of recruitment on scallop biomass in open and closed areas. The shell height at which 50% of the scallops were vulnerable to the dredge (L_{50}) on Georges Bank was strongly associated with year-class strength, with decreases in L_{50} associated with increases in recruitment, whereas L_{50} was stable in the Mid-Atlantic region. The SARC concluded that expected shifts in the size distribution of landings, due to increased dredge ring size and decreased maximum crew size, did not occur and that historical patterns of the catch size composition demonstrate that these shifts were primarily influenced by year-class strength and meat count regulations.

Based on a projection of the adjusted survey size frequency distribution and incorporating growth rates, scallop biomass in the Georges Bank closed areas is expected to double by summer 1997. In light of these findings, the SARC concluded that the closed areas provide scallop conservation opportunities that need to be considered in the future management of the resource. The SARC expressed concern that when the closed areas are reopened, given the current harvesting capacity of the fishery, gains in biomass inside the closed areas would be rapidly depleted since abundance is low in the open areas of Georges Bank as well as in the Mid-Atlantic region. The eventual need to open these closed areas to fishing to "cultivate" scallop habitat was also recognized. Therefore, the SARC recommended that managers should consider these factors before reopening the closed areas and investigate the opportunity to transition from a recruitment-driven fishery to a sustainable-yield fishery in which the larger scallops are targeted.

Since trips split between statistical areas could not be identified from the 1994-1996 vessel logbook data, the SARC decided not to use the number of trips by region and gear type as a measure of fishing effort. It was agreed that no other measures of fishing effort were available from either the vessel logbook database or the days-at-sea enforcement database. The absence of accurate measures of fishing effort may undermine the implementation of effort reduction plans specified in Amendment 4 of the Scallop FMP.

Attention was drawn to the fact that overfishing, with respect to the biological reference point ($F_{5\%}$), is occurring in the Mid-Atlantic region. SARC members emphasized the need to expeditiously implement effort reduction measures in this region given the low stock size and lack of significant recruitment. In addition, the SARC noted that the moderate levels of abundance and fishing mortality in the Georges Bank region were due to the closure of nearly half of the traditional fishing grounds and that elsewhere in this region the fishing mortality rate is greater than the biological reference point.

Research Recommendations

- The analyses conducted in this assessment reinforce the SAW-22 recommendation to establish a field to permit a direct link between the dealer and vessel logbook databases and expedite logbook auditing.

- Increase biological sampling effort at major ports where scallops are landed, including increased sampling of scallops landed with trawls.

- Incorporate meat count information contained on the dealer reports into catch estimation procedures.

- Optimize sampling design for scallop samples collected from the Domestic Sea Sampling Program (i.e., compute *minimum* number of samples necessary to characterize the length-frequency distribution of kept and discarded scallops from a scallop trip and determine a method for accurately quantifying scallop discard weights).

- Investigate the potential to utilize closed areas to ensure sufficient spawning stock biomass and improve yield per recruit.

- Conduct tagging studies in the closed areas of Georges Bank to assess scallop growth rates and to evaluate the probability of capture by scallop gear, particularly with respect to bottom type.

- Investigate the disparity between fishing mortality rates from the modified DeLury model and those derived from survey estimates.

- Quantify the area sampled by the NEFSC survey dredge and examine the effects of selecting alternate stations in areas where the gear cannot be towed.

- Investigate the use of Canadian survey data to fill in the gap in the time series created by the lack of sampling on the Northeast Peak of Georges Bank.

- Evaluate the potential effects of applying a single biological reference point to the Georges Bank and Mid-Atlantic regions.

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Table B1. United States and Canadian sea scallop landings (metric tons of meats) from the Northwest Atlantic (NAFO Subareas 5 and 6), 1887-1996.

Year	USA[1]	Year	USA	Canada[2]	Total
1887	112	1951	8,503	91	8,594
1888[5]	91	1952	8,451	91	8,542
1889	141	1953	10,713	136	10,849
1892	53	1954	7,997	91	8,088
1897	435	1955	10,036	136	10,172
1898	156	1956	9,102	317	9,419
1899[5]	24	1957	9,523	771	10,294
1900[5]	79	1958	8,608	1,179	9,787
1901	286	1959	11,178	2,378	13,556
1902	61	1960	12,065	3,470	15,535
1903[5]	62	1961	12,456	4,565	17,021
1904	216	1962	11,174	5,715	16,889
1905	200	1963	9,038	5,898	14,936
1906[5]	255	1964	7,704	5,922	13,626
1907[5]	236	1965	9,105	7,052	16,157
1908	834	1966	7,237	7,669	14,906
1909[5]	843	1967	4,646	5,025	9,671
1910[5]	919	1968	5,473	5,243	10,716
1911[5]	663	1969	3,363	4,320	7,683
1912[5]	842	1970	2,613	4,097	6,710
1913[5]	353	1971	2,593	3,908	6,501
1914[5]	386	1972	2,655	4,177	6,832
1916[5]	266	1973	2,401	4,223	6,624
1919	89	1974	2,722	6,137	8,859
1921	38	1975	4,422	7,414	11,836
1924	154	1976	8,721	9,780	18,501
1926	506	1977	11,103	13,091	24,194
1928	216	1978	14,482	12,189	26,671
1929	1,130	1979	14,256	9,207	23,463
1930	1,111	1980	12,566	5,239	17,805
1931	1,058	1981	11,742	8,018	19,760
1932	1,517	1982	9,044	4,330	13,374
1933	2,009	1983	8,707	2,895	11,602
1935	1,955	1984	7,739	2,042	9,781
1937	3,989	1985	6,742	3,851	10,593
1938	4,041	1986	8,661	4,705	13,366
1939	4,440	1987	13,227	6,810	20,037
1940	3,467	1988	13,198	4,405	17,603
1941[6]	3,622	1989	14,776	4,676	19,452
1942	3,258	1990	17,174	5,130	22,304
1943	2,508	1991	16,998	5,833	22,831
1944	2,209	1992	14,038	5,129	19,167
1945	2,590	1993	7,296	6,160	13,456
1946	5,236	1994[3]	7,534	5,003	12,537
1947	6,647	1995[3]	7,838	1,984	9,822
1948	7,546	1996[3,4]	3,912	n/a	n/a
1949	8,299				
1950	9,063				

[1]USA landings: 1887-1960 from Lyles (1969); 1961-1975 from Fishery Statistics of the United States; 1963-1982 from ICNAF and NAFO Statistical Bulletins; 1964-1994 from Detailed Weighout Data, Northeast Fisheries Center, Woods Hole, Mass. [2]Canadian landings: 1951 1958 from ICNAF Statistical Bulletins and Caddy (1975); 1953-1988 from Mohn et al. (1989) for Georges Bank and from ICNAF/NAFO Bulletins for Gulf of Maine and Mid Atlantic; 1989 from NAFO SCS Doc. 90/21; 1990, 1991 from DFO, Statistics Branch, Halifax. [3]USA landings are estimated *preliminarily* from VTR logbook and dealer report. [4]USA landings from January-June 1996. [5]Maine landings only from Baird (1956). [6]USA landings for 1941 from O'Brien (1961).

Table B2. Scallop landings (mt) by region, gear type, and year. Data for 1964-1988 were taken from Serchuk and Wigley (1988). Data for 1989-1993 were taken from NEFSC commercial weighout database; canvass data not included. Data for April 1994 - June 1996 were estimated from Vessel Trip Reports and Dealer Logs.

	Gulf of Maine				Georges Bank				Southern New England				Mid-Atlantic				Uncl.	Total			
Year	Dredge	Trawl	Other	Sum	Dredge	Trawl	Other	Sum	Dredge	Trawl	Other	Sum	Dredge	Trawl	Other	Sum	Other	Dredge	Trawl	Other	Sum
1964	-	0	192	192	-	0	6,241	6,241	-	52	3	55	-	-	-	-	137	-	52	6,436	6,626
1965	-	0	115	115	-	3	1,480	1,483	-	2	24	26	-	-	-	-	3,974	-	5	1,619	5,598
1966	-	0	93	93	-	0	883	884	-	0	8	8	-	-	-	-	4,071	-	1	984	5,056
1967	-	0	80	80	-	4	1,217	1,221	-	0	8	8	-	-	-	-	1,873	-	4	1,305	3,182
1968	-	0	113	113	-	0	993	994	-	0	56	56	-	0	2,437	2,437	-	-	0	3,599	3,599
1969	-	1	122	123	-	8	1,316	1,324	-	0	18	19	-	5	846	851	-	-	14	2,302	2,317
1970	-	0	132	132	-	5	1,410	1,415	-	0	6	6	-	14	459	473	-	-	19	2,006	2,026
1971	-	4	358	362	-	18	1,311	1,329	-	0	7	7	-	0	274	274	-	-	22	1,949	1,971
1972	-	1	524	525	-	5	816	821	-	0	2	2	-	5	653	658	-	-	11	1,995	2,006
1973	-	0	460	460	-	15	1,065	1,080	-	0	3	3	-	4	245	249	-	-	19	1,773	1,792
1974	-	0	223	223	-	15	911	926	-	0	4	5	-	0	937	938	-	-	16	2,076	2,091
1975	-	6	741	746	-	13	844	857	-	8	42	50	-	52	1,506	1,558	-	-	80	3,132	3,212
1976	-	3	364	366	-	38	1,723	1,761	-	4	3	7	-	317	2,972	3,288	-	-	361	5,061	5,422
1977	-	4	254	258	-	27	4,709	4,736	-	1	10	11	-	27	2,564	2,591	-	-	58	7,536	7,595
1978[1]	242	1	0	243	5,532	37	0	5,569	25	2	0	27	4,175	21	0	4,196	-	9,974	61	0	10,035
1979	401	5	1	407	6,253	25	7	6,285	61	5	0	66	2,857	29	1	2,888	-	9,572	64	9	9,645
1980	1,489	122	3	1,614	5,382	34	2	5,419	130	3	0	133	1,966	9	0	1,975	0	8,968	169	4	9,142
1981	1,225	73	7	1,305	7,787	56	0	7,843	68	1	0	69	726	5	0	731	-	9,806	135	7	9,948
1982	631	28	5	664	6,204	119	0	6,322	126	0	0	126	1,602	6	2	1,610	-	8,562	153	7	8,723
1983	815	72	7	895	4,247	32	4	4,284	243	1	0	243	3,081	18	10	3,109	-	8,386	124	21	8,530
1984	651	18	10	678	3,011	29	3	3,043	161	3	0	164	3,647	26	2	3,675	-	7,470	76	14	7,560
1985	408	3	10	421	2,860	34	0	2,894	77	4	0	82	3,227	47	1	3,276	-	6,572	88	11	6,672
1986	308	2	6	316	4,428	10	0	4,438	76	2	0	78	3,257	101	0	3,359	-	8,068	115	7	8,190
1987	373	0	9	382	4,821	30	0	4,851	67	1	0	68	7,488	315	1	7,803	-	12,749	346	10	13,104
1988	506	7	13	526	6,036	18	0	6,054	65	4	0	68	5,774	402	2	6,178	-	12,381	430	16	12,826
1989	600	0	44	644	5,637	25	0	5,661	127	11	0	138	7,549	422	2	7,973	-	13,913	458	45	14,416
1990	545	0	28	574	9,972	10	0	9,982	110	6	0	116	5,954	476	4	6,435	-	16,581	493	32	17,107
1991	527	3	75	605	9,235	77	0	9,311	55	16	0	71	6,195	808	9	7,011	-	16,012	903	84	16,999
1992	676	2	45	722	8,230	7	0	8,238	119	5	0	124	4,386	563	5	4,955	-	13,411	577	50	14,039
1993	763	2	32	797	3,637	18	0	3,655	65	1	0	66	2,382	392	3	2,778	-	6,848	413	36	7,296
1994[2]	519	3	3	525	1,133	3	1	1,137	n/a	n/a	n/a	n/a	5,176	688	9	5,872	-	6,827	693	13	7,534
1995[2]	717	3	17	737	1,000	2	4	1,006	n/a	n/a	n/a	n/a	5,338	751	6	6,094	-	7,055	756	26	7,838
1996[3]	247	9	9	265	659	2	1	662	n/a	n/a	n/a	n/a	2,741	242	2	2,985	-	3,647	254	11	3,912
1964-1995																					
Mean	633	11	128	495	5,300	22	779	3,783	98	4	7	63	4,155	197	462	3,330		10,175	210	1,318	7,565
Min	242	0	0	80	1,000	0	0	821	25	0	0	2	726	0	0	249		6,572	0	0	1,792
Max	1,489	122	741	1614	9,972	119	6,241	9,982	243	52	56	243	7,549	808	2,972	7,973		16,581	903	7,536	17,107

[1]Previous to 1978, dredge trips are included in the "other" gear type. [2]Estimated from Vessel Trip Reports and Dealer Logs, preliminary only. [3]From January-June.

Table B3. Distribution of USA and Canadian sea scallop landings (mt, meats) in the three principal sea scallop fishing regions on Georges Bank, 1957-1993.

	USA				Canada				Total			
Year	Great South Channel	Southeast Part	Northern Edge and Peak	Total	Great South Channel	Southeast Part	Northern Edge and Peak	Total	Great South Channel	Southeast Part	Northern Edge and Peak	Total
1957	1,491	628	5,727	7,846	8	-	763	771	1,499	628	6,490	8,617
1958	1,241	457	4,833	6,531	-	-	1,179	1,179	1,241	457	6,012	7,710
1959	1,951	2,799	3,731	8,481	-	-	2,378	2,378	1,951	2,799	6,109	10,859
1960	1,788	4,469	3,675	9,932	-	-	3,470	3,470	1,788	4,469	7,145	13,402
1961	2,132	1,812	6,716	10,660	-	-	4,565	4,565	2,132	1,812	11,281	15,225
1962	1,744	1,841	6,105	9,690	-	-	5,715	5,715	1,744	1,841	11,820	15,405
1963	2,057	2,215	3,638	7,910	-	472	5,426	5,898	2,057	2,687	9,064	13,808
1964	2,569	1,909	1,763	6,241	-	118	5,804	5,922	2,569	2,027	7,567	12,163
1965	677	390	416	1,483	-	178	4,256	4,434	677	568	4,672	5,917
1966	716	24	144	884	-	-	4,878	4,878	716	24	5,022	5,762
1967	641	311	269	1,221	-	-	5,019	5,019	641	311	5,288	6,240
1968	713	149	163	1,025	-	-	4,820	4,820	713	149	4,983	5,845
1969	576	227	522	1,325	-	-	4,318	4,318	576	227	4,840	5,643
1970	1,069	159	187	1,415	41	-	4,056	4,097	1,110	159	4,243	5,512
1971	1,091	214	24	1,329	547	-	3,361	3,908	1,638	214	3,385	5,237
1972	623	64	134	821	417	-	3,744	4,161	1,040	64	3,878	4,982
1973	890	173	17	1,080	1,140	-	3,083	4,223	2,030	173	3,100	5,303
1974	783	121	21	925	552	307	5,278	6,137	1,335	428	5,299	7,062
1975	566	175	116	857	593	74	6,747	7,414	1,159	249	6,863	8,271
1976	1,583	142	45	1,770	781	-	8,980	9,761	2,364	142	9,025	11,531
1977	4,121	277	407	4,805	262	-	12,827	13,089	4,383	277	13,234	17,894
1978	3,918	366	1,285	5,569	-	-	12,189	12,189	3,918	366	13,474	17,758
1979	3,996	758	1,819	6,573	-	-	9,207	9,207	3,996	758	11,026	15,780
1980	2,994	685	1,941	5,620	-	-	5,221	5,221	2,994	685	7,162	10,841
1981	2,940	515	4,966	8,421	-	-	8,013	8,013	2,940	515	12,979	16,434
1982	3,391	575	2,543	6,509	-	-	4,306	4,306	3,391	575	6,849	10,815
1983	2,439	432	1,457	4,328	-	-	2,748	2,748	2,439	432	4,205	7,076
1984	1,633	691	747	3,071	-	-	1,945	1,945	1,633	691	2,692	5,016
1985	1,554	403	992	2,949	-	-	3,812	3,812	1,554	403	4,804	6,761
1986	2,744	654	1,113	4,511	-	-	4,670	4,670	2,744	654	5,783	9,181
1987	2,404	265	2,216	4,885	-	-	6,793	6,793	2,404	265	9,009	11,678
1988	3,124	835	2,124	6,083	-	-	4,336	4,336	3,124	835	6,460	10,419
1989	2,771	589	2,326	5,686	-	-	4,676	4,676	2,771	589	7,002	10,362
1990	3,974	1,009	5,026	10,009	-	-	5,218	5,218	3,974	1,009	10,244	15,227
1991	5,655	904	2,752	9,311	-	-	5,805	5,805	5,655	904	8,557	15,116
1992	4,817	1,123	2,298	8,238	-	-	6,151	6,151	4,817	1,123	8,449	14,389
1993	2,065	501	1,089	3,655	-	-	6,183	6,183	2,065	501	7,272	9,838
1994[1]	729	225	182	1,136	-	-	5,003	5,003	729	225	5,185	6,139
1995[1]	465	135	407	1,007	-	-	1,984	1,984	465	135	2,391	2,991
1996[1,2]	447	145	70	662	-	-	-	-	n/a	n/a	n/a	n/a

[1]USA landings are estimated preliminarily from VTR logbook and dealer report. [2]USA landings from Jan.-Jun. 1996. Great South Channel = Statistical Areas 521, 522, & 526; Southeast Part = Statistical Area 525;Northern Edge and Peak = Statistical Areas

Table B4. Summary of sea scallop shell samples collected by the NEFSC Domestic Sea Sampling Program in the Georges Bank and Mid-Atlantic regions, 1992-1996.

	Number of trips (Split trips)				Total sampled trips	Number of shells				
Year	Q1	Q2	Q3	Q4		Q1	Q2	Q3	Q4	Sum
Georges Bank										
1992	1	3	2	4	10	993	15,156	4,642	22,075	42,866
1993	4	3	2	2	10	8,801	23,484	10,444	6,170	48,899
1994	1	1	1	4	4	5,056	13,707	6,844	14,727	40,334
1995	1	0	2	2	4	3,441	0	9,647	8,034	21,122
1996	3	3	-	-	4	13,859	14,784	-	-	28,643
Mid-Atlantic										
1992	2	1	2	2	7	3,791	6349	5,959	8,394	24,493
1993	4	4	1	2	11	18,848	18,655	6,064	5,830	49,397
1994	6	3	3	4	14	37,882	21,198	27,562	13,825	100,467
1995	8	5	3	2	11	36,810	36,529	10,780	6,663	90,782
1996	4	5	-	-	9	22,562	36,376	-	-	58,938

Table B5. Estimated ratios of discarded and kept scallops for vessels using scallop dredges in the Georges Bank region based on data from the NEFSC Domestic Sea Sampling Program, 1992-1996.

Area	Item	1992	1993	1994	1995	1996
US Northern Edge and Peak	lb-kept	104,918	143,110	39,890	3,641	8,540
	lb-discard	9,792	4,734	0	3	0
	ratio	0.09333	0.03308	0	0.00082	0
	var(r)	0.0005	0.00005	0	0	0
	# tows	241	372	141	34	22
Great South Channel	lb-kept	324,542	219,494	105,043	68,723	295,121
	lb-discard	16,404	27,988	369	2,964	29,126
	ratio	0.05055	0.12751	0.00351	0.04313	0.09869
	var(r)	0.00018	0.00007	0	0.00006	0.00006
	# tows	461	520	571	296	632
Southeast Part	lb-kept	14,958	51,372	1,304	23,065	4,756
	lb-discard	0	2	2	104	0
	ratio	0	0.00004	0.00153	0.00451	0
	var(r)	0	0	0	0	0
	# tows	35	197	8	89	22
Georges Bank	lb-kept	444,418	413,976	146,237	95,429	308,417
	lb-discard	26,196	32,724	371	3,071	29,126
	ratio	0.05894	0.07905	0.00253	0.03218	0.09444
	var(r)	0.00012	0.00003	0	0.00003	0.00006
	# tows	737	1089	720	419	676
	Total # of trips sampled	10	10	4	4	4

Table B6. Estimated ratios of discarded and kept scallops for vessels using scallop dredges in the Mid-Atlantic region based on data from the NEFSC Domestic Sea Sampling Program, 1992-1996.

Area	Item	1992	1993	1994	1995	1996
Delmarva	lb-kept	78,624	92,376	575,797	205,472	75,405
	lb-discard	224	1,374	116,206	13,006	837
	ratio	0.00285	0.01487	0.20182	0.0633	0.0111
	var(r)	0	0.00001	0.00041	0.00003	0.00003
	# tows	188	368	1,084	757	299
New York Bight	lb-kept	159,978	295,568	179,997	331,974	328,100
	lb-discard	5,568	464	3,555	15,563	1,766
	ratio	0.0348	0.00157	0.01975	0.04688	0.00538
	var(r)	0.00003	0	0.00003	0.00003	0
	# tows	408	985	554	1,001	979
Virginia-North Carolina	lb-kept	22,260	-	30,836	2,695	28,396
	lb-discard	1,470	-	17,920	55	0
	ratio	0.06604	-	0.58114	0.02041	0
	var(r)	0.00057	-	0.02943	0.00009	0
	# tows	40	-	25	10	125
Mid-Atlantic	lb-kept	260,862	387,944	786,630	540,141	431,901
	lb-discard	7,262	1,838	137,680	28,624	2,603
	ratio	0.02784	0.00474	0.17503	0.05299	0.00603
	var(r)	0.00001	0	0.00029	0.00001	0
	# tows	636	1,353	1,663	1,768	1,403
	Total # of trips sampled	7	11	14	11	9

Table B7. Summary of NEFSC commercial scallop shell samples collected from vessels using scallop dredges and landing sea scallops in Georges Bank and Mid-Atlantic ports during 1982-1996.

	Samples				Shells			
Year	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Georges Bank								
1982	18	28	19	5	3,225	5,511	3,430	1,065
1983	4	18	12	4	729	3,872	2,408	708
1984	0	11	6	13	0	1,939	852	2,146
1985	7	6	17	5	1,208	1,317	3,585	1,196
1986	9	22	29	25	2,494	5,640	7,007	5,602
1987	8	7	35	14	1,878	1,854	9,028	3,659
1988	6	29	34	15	1,356	7,211	8,874	3,901
1989	2	15	33	21	757	3,515	7,864	4,935
1990	8	27	25	17	2,118	8,165	5,985	5,066
1991	26	27	28	19	7,788	7,653	8,450	5,178
1992	20	41	37	36	5,288	12,472	11,377	11,956
1993	21	36	53	22	6,543	11,070	14,600	5,372
1994	11	16	7	13	2,448	3,367	1,575	3,361
1995	0	0	0	1	0	0	0	273
1996[1]	5	26	n/a	n/a	908	5,253	n/a	n/a
Mid-Atlantic								
1982	3	8	12	9	737	1,999	2,670	2,406
1983	10	32	16	10	2,590	8,590	3,730	2,221
1984	16	17	14	12	3,326	4,020	4,260	3,611
1985	4	29	17	17	981	7,520	4,662	3,494
1986	6	13	19	14	1,682	3,151	4,501	3,196
1987	17	44	44	21	4,070	11,400	11,753	4,251
1988	25	35	34	17	6,625	8,068	7,789	4,200
1989	27	40	31	18	7,008	9,644	7,033	3,580
1990	38	25	4	7	9,069	6,177	1,190	1,562
1991	6	17	16	8	1,240	3,950	3,284	1,490
1992	20	40	21	15	4,308	8,574	4,399	3,717
1993	14	26	20	5	2,931	6,270	4,552	1,014
1994	9	5	5	4	2,527	1,464	1,851	880
1995	3	5	14	3	600	1,000	2,756	490
1996[1]	0	3	n/a	n/a	0	1,676	n/a	n/a

[1]Based on preliminary text files.

Table B8. USA sea scallop research survey relative abundance indices (standardized stratified mean number and mean weight per tow), [meats only, kg], mean shell height (mm), mean meat weight (g) per scallop, and average meat count (number of scallop meats per pound) of sea scallops from NEFSC surveys on Georges Bank, 1975, 1977-1996. Data are presented by principal scallop areas for Georges Bank[1]. Survey indices are presented for pre-recruit (< 70 mm shell height), recruit (≥ 70 mm shell height), and total scallops per tow.

Area	Year	No. of tows	Standardized stratified mean number per tow			Standardized stratified mean weight (kg) per tow[2]			Mean shell height	Average meat count
			Pre-recruit	Recruit	Total	Pre-recruit	Recruit	Total		
Great South Channel	1975	58	45.1	29.9	75.0	0.11	0.81	0.92	76.4	37.0
	1977	30	6.3	89.1	95.4	0.02	1.94	1.96	101.3	22.1
	1978	46	7.7	49.7	57.4	0.02	1.15	1.17	101.2	22.2
	1979	47	6.8	88.2	95.0	0.01	1.53	1.54	93.2	28.0
	1980	40	79.7	30.2	109.9	0.12	0.55	0.67	58.2	74.6
	1981	56	15.5	36.5	52.0	0.03	0.65	0.68	80.5	34.8
	1982	61	213.8	53.0	266.8	0.49	0.67	1.16	58.6	103.9
	1983	69	19.0	55.8	74.8	0.06	0.77	0.83	81.4	41.0
	1984	69	13.6	17.7	31.3	0.03	0.36	0.39	77.3	36.7
	1985	77	40.3	47.3	87.6	0.11	0.76	0.87	75.0	45.7
	1986	68	115.3	37.0	152.3	0.24	0.58	0.82	59.5	84.2
	1987	86	84.6	56.1	140.7	0.17	0.72	0.89	63.6	71.6
	1988	91	32.5	36.0	68.5	0.08	0.46	0.54	70.6	57.7
	1989	88	21.7	15.1	36.8	0.06	0.27	0.33	72.0	50.5
	1990	76	258.8	49.9	308.7	0.54	0.60	1.14	55.9	122.5
	1991	86	432.1	64.2	496.3	0.80	0.71	1.51	52.8	149.5
	1992	85	222.8	171.8	394.6	0.78	1.38	2.16	67.5	82.8
	1993	77	30.6	24.5	55.1	0.11	0.28	0.39	71.7	63.3
	1994	88	18.7	37.6	56.3	0.04	0.44	0.48	74.2	53.4
	1995	90	120.7	41.2	161.9	0.31	0.55	0.87	62.7	97.8
	1996	86	60.5	87.3	147.8	0.17	1.26	1.43	75.7	47.0
Southeast Part	1975	21	1.8	38.4	40.2	<0.01	1.02	1.02	110.3	17.8
	1977	21	3.2	27.2	30.4	0.01	0.68	0.69	103.6	20.0
	1978	18	2.2	27.1	29.3	<0.01	0.93	0.93	117.2	14.2
	1979	20	7.7	21.2	28.9	0.01	0.71	0.72	99.4	18.2
	1980	20	21.5	41.7	63.2	0.03	0.71	0.74	78.2	38.8
	1981	19	1.4	19.4	20.8	<0.01	0.46	0.46	102.5	20.5
	1982	22	0.8	9.8	10.6	<0.01	0.32	0.32	113.5	15.2
	1983	20	11.3	9.2	20.5	0.02	0.25	0.27	78.1	34.0
	1984	20	4.6	12.9	17.5	0.01	0.23	0.24	85.7	33.0
	1985	28	9.1	11.8	20.9	0.02	0.22	0.24	75.3	39.9
	1986	32	28.9	20.6	49.5	0.05	0.41	0.46	66.2	48.5
	1987	32	23.1	39.6	62.7	0.06	0.60	0.66	79.0	42.8
	1988	32	1.4	16.1	17.5	<0.01	0.32	0.32	96.9	24.6
	1989	31	23.6	11.8	35.4	0.07	0.23	0.30	70.2	54.4
	1990	32	1.6	8.4	10.0	<0.01	0.15	0.15	88.7	30.3
	1991	32	18.5	14.1	32.6	0.04	0.21	0.25	65.2	60.2
	1992	32	10.3	20.5	30.8	0.03	0.34	0.37	83.3	37.7
	1993	32	2.4	9.5	11.8	0.01	0.23	0.24	97.5	22.8
	1994	32	19.6	8.9	28.5	0.03	0.25	0.28	66.9	46.2
	1995	32	13.7	13.5	27.1	0.04	0.28	0.32	79.1	67.6
	1996	32	20.4	12.1	32.5	0.04	0.24	0.29	69.2	51.2

[1]Great South Channel: Strata 46-47, 49-55; Southeast Part: Strata 58-60; Northern Edge and Peak: Strata 61-662, 71-72, 74. [2]Mean meat weight derived by applying the 1977-1982 USA Mid-Atlantic research survey sea scallop shell height meat weight equation, ln [Meat Weight (g)] = -11.7656 + 3.1693 ln [Shell Height (mm)], (n = 5863, r = 0.98) to the survey shell height frequency distributions. [3]Not sampled. [4]Not calculated due to incomplete survey coverage. [5]Stratum 72 not sampled, excluded from analyses.

Table B8. (Continued)

Area	Year	No. of tows	Standardized stratified mean number per tow: Pre-recruit	Recruit	Total	Standardized stratified mean weight (kg) per tow[2]: Pre-recruit	Recruit	Total	Mean shell height	Average meat count
USA Northern Edge and Peak	1985	67	21.8	26.6	48.4	0.06	0.39	0.45	72.2	48.9
	1986	70	45.6	28.6	74.2	0.13	0.48	0.61	70.4	55.2
	1987	71	62.0	54.6	116.6	0.12	0.73	0.85	67.1	62.1
	1988	71	65.8	60.9	126.7	0.15	0.77	0.92	66.4	62.6
	1989[3]	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
	1990[4]	65	66.9	196.8	263.7	0.22	1.83	2.05	75.8	58.3
	1991	71	118.7	66.9	185.6	0.31	0.85	1.16	66.1	72.4
	1992	69	26.1	45.0	71.1	0.08	0.60	0.68	77.6	47.3
	1993	67	2.7	15.6	18.3	0.01	0.25	0.26	88.6	32.4
	1994	70	14.9	10.4	25.3	0.02	0.22	0.24	69.4	47.7
	1995	71	81.6	14.3	95.9	0.21	0.25	0.46	59.1	119.1
	1996	71	103.3	83.3	186.7	0.25	1.22	1.47	70.7	57.5
USA Georges Bank	1985	172	26.5	31.8	58.3	0.07	0.50	0.57	74.2	46.4
	1986	170	61.3	28.9	90.2	0.14	0.49	0.63	64.4	64.9
	1987	189	62.6	51.9	114.5	0.12	0.70	0.82	66.8	63.0
	1988	194	38.0	40.8	78.8	0.09	0.54	0.63	69.4	56.6
	1989[5]	-	-	-	-	-	-	-	-	-
	1990[4]	173	135.2	87.8	223.0	0.31	0.89	1.20	63.9	84.1
	1991	189	224.1	51.4	278.2	0.45	0.65	1.10	56.4	114.8
	1992	186	102.7	91.2	193.9	0.36	0.86	1.22	69.4	72.3
	1993	176	14.0	17.8	31.8	0.05	0.26	0.31	77.5	46.9
	1994	190	17.5	21.1	38.6	0.04	0.31	0.35	71.8	50.6
	1995	193	82.4	25.1	107.5	0.21	0.38	0.60	65.0	99.0
	1996	189	67.6	69.2	136.8	0.17	1.02	1.19	72.8	52.1
Canada Northern Edge and Peak	1985	41	186.0	460.3	646.3	0.58	4.20	4.78	74.1	61.3
	1986	146	379.6	466.0	845.6	0.80	6.01	6.81	72.3	56.3
	1987	47	293.0	231.7	524.7	0.59	3.04	3.63	66.9	65.6
	1988	48	153.7	227.1	380.8	0.36	2.77	3.13	72.8	55.3
	1989[3]	N/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
	1990	41	431.7	287.9	719.6	0.68	3.80	4.48	61.9	72.9
	1991	14	206.4	98.3	304.7	0.53	1.62	2.15	66.7	64.3
	1992[3]	N/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
	1993	48	19.5	199.2	218.7	0.06	3.25	3.31	92.8	30.0
	1994	47	110.6	237.2	347.8	0.19	3.54	3.73	78.5	42.3
	1995	48	185.4	444.0	629.4	0.48	4.85	5.33	75.4	60.1
	1996	29	271.2	172.7	443.9	0.51	2.78	3.30	66.6	61.1

[1]Great South Channel: Strata 46-47, 49-55; Southeast Part: Strata 58-60; Northern Edge and Peak: Strata 61-662, 71-72, 74. [2]Mean meat weight derived by applying the 1977-1982 USA Mid-Atlantic research survey sea scallop shell height meat weight equation, ln [Meat Weight (g)] = -11.7656 + 3.1693 ln [Shell Height (mm)], (n = 5863, r = 0.98) to the survey shell height frequency distributions. [3]Not sampled. [4]Not calculated due to incomplete survey coverage. [5]Stratum 72 not sampled, excluded from analyses.

Table B8. (Continued)

Area	Year	No. of tows	Standardized stratified mean number per tow: Pre-recruit	Recruit	Total	Standardized stratified mean weight (kg) per tow[2]: Pre-recruit	Recruit	Total	Mean shell height	Average meat count
Georges Bank (all areas)	1975	130	51.7	74.6	126.3	0.13	1.34	1.47	79.9	39.0
	1977	122	34.3	218.3	252.6	0.12	3.18	3.30	87.6	34.7
	1978	140	79.7	184.0	263.7	0.14	3.88	4.02	87.1	29.8
	1979	220	36.6	152.3	188.9	0.10	2.70	2.80	88.6	30.6
	1980	371	377.4	92.3	469.7	0.52	1.37	1.89	53.4	112.6
	1981	176	97.2	152.4	249.6	0.22	1.62	1.84	70.6	61.5
	1982	163	91.0	51.2	142.2	0.22	0.74	0.96	66.5	66.9
	1983	171	31.9	38.2	70.1	0.06	0.63	0.69	73.4	46.3
	1984	171	148.7	34.6	183.3	0.15	0.57	0.72	49.1	114.9
	1985	213	56.3	111.6	167.9	0.17	1.19	1.36	74.1	56.2
	1986	316	129.9	123.0	252.9	0.28	1.68	1.96	70.1	58.5
	1987	236	105.5	85.4	190.9	0.21	1.14	1.35	66.9	64.3
	1988	242	59.5	75.6	135.1	0.14	0.96	1.10	71.2	55.9
	1989[4]	-	-	-	-	-	-	-	-	-
	1990[5]	214	193.6	127.3	320.9	0.38	1.47	1.85	63.0	78.7
	1991	203	220.8	62.3	283.1	0.46	0.83	1.29	58.5	99.2
	1992[4]	-	-	-	-	-	-	-	-	-
	1993	224	15.0	51.6	66.6	0.05	0.82	0.87	86.8	34.9
	1994	237	51.4	97.0	148.4	0.08	1.48	1.56	77.6	42.8
	1995	238	101.6	103.0	204.5	0.26	0.37	0.57	66.9	91.8
	1996[6]	-	-	-	-	-	-	-	-	-

[1]Great South Channel: Strata 46-47, 49-55; Southeast Part: Strata 58-60; Northern Edge and Peak: Strata 61-662, 71-72, 74. [2]Mean meat weight derived by applying the 1977-1982 USA Mid-Atlantic research survey sea scallop shell height meat weight equation, ln [Meat Weight (g)] = -11.7656 + 3.1693 ln [Shell Height (mm)], (n = 5863, r = 0.98) to the survey shell height frequency distributions. [3]Not sampled. [4]Not calculated due to incomplete survey coverage. [5]Stratum 72 not sampled, excluded from analyses.

Table B9. USA sea scallop research survey relative abundance indices (standardized stratified mean number and mean weight per tow), [meats only, kg], mean shell height (mm), mean meat weight (g) per scallop, and average meat count (number of scallop meats per pound) of sea scallops from NEFSC surveys in the Mid-Atlantic, 1975, 1977-1996. Data are presented by principal scallop areas in the Mid-Atlantic[1]. Survey indices are presented for pre-recruit (< 70 mm shell height), recruit (≥ 70 mm shell height) and total scallops per tow.

Area	Year	No. of tows	Standardized stratified mean number per tow			Standardized stratified mean weight (kg) per tow[2]			Mean shell height	Average meat count
			Pre-recruit	Recruit	Total	Pre-recruit	Recruit	Total		
Virginia-North Carolina	1975	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
	1977	1	0	10.0	10.0	0	0.23	0.23	108.0	20.0
	1978	3	15.3	50.3	65.6	0.06	1.10	1.16	91.8	25.7
	1979	3	23.7	22.7	46.4	0.04	0.37	0.41	71.7	51.3
	1980	3	6.6	39.0	45.6	0.02	0.59	0.61	87.6	34.1
	1981	3	0.9	7.6	8.5	<0.01	0.20	0.20	107.7	18.8
	1982	7	0.4	3.7	4.1	<0.01	0.12	0.12	111.5	15.8
	1983	8	25.8	11.7	37.5	0.10	0.36	0.46	78.1	37.2
	1984	9	0.2	14.6	14.8	<0.01	0.27	0.27	98.7	25.3
	1985	10	1.7	7.3	9.0	<0.01	0.23	0.23	104.8	17.8
	1986	10	5.6	1.8	7.4	<0.02	0.04	0.06	69.1	55.9
	1987	10	0.1	2.1	2.2	<0.01	0.04	0.04	93.4	28.3
	1988	10	3.1	11.0	14.1	0.01	0.21	0.22	89.8	28.9
	1989	10	35.7	5.9	41.6	0.07	0.13	0.20	57.9	92.9
	1990	6	36.5	93.1	129.6	0.07	0.88	0.95	73.2	61.7
	1991	10	37.2	32.0	69.2	0.10	0.45	0.55	71.6	57.5
	1992	10	4.1	29.2	33.3	0.01	0.39	0.40	85.9	37.7
	1993	10	245.3	59.1	304.4	0.83	0.54	1.37	64.3	100.5
	1994	10	13.3	145.5	158.8	0.05	1.30	1.35	79.8	53.5
	1995	10	55.8	11.7	67.5	0.11	0.15	0.26	57.1	118.4
	1996	10	30.1	1.0	31.0	0.06	0.02	0.08	53.6	177.7
Delmarva	1975	15	36.2	24.0	60.2	0.11	0.44	0.55	75.2	49.3
	1977	10	10.7	47.5	58.2	0.03	0.91	0.94	92.2	28.1
	1978	45	27.3	75.8	103.2	0.09	1.58	1.67	91.6	28.0
	1979	43	25.4	64.6	90.0	0.04	0.95	0.99	78.8	41.2
	1980	43	81.1	35.9	117.0	0.13	0.68	0.81	63.3	65.7
	1981	41	4.7	14.3	19.0	0.01	0.32	0.33	90.3	26.2
	1982	44	10.0	18.6	28.6	0.04	0.43	0.47	89.8	27.8
	1983	49	25.7	16.5	42.2	0.09	0.37	0.46	77.0	41.7
	1984	52	19.8	19.3	39.1	0.03	0.38	0.41	69.8	43.7
	1985	54	70.4	35.8	106.2	0.15	0.43	0.58	58.9	82.5
	1986	62	123.5	83.5	207.0	0.37	0.93	1.30	68.5	72.3
	1987	61	52.9	59.5	112.4	0.16	0.74	0.90	74.1	56.7
	1988	62	75.9	39.1	115.0	0.15	0.62	0.77	64.6	67.9
	1989	62	113.1	97.2	210.3	0.24	1.09	1.33	67.5	71.6
	1990	62	27.7	80.9	108.6	0.06	0.87	0.93	76.9	53.0
	1991	61	53.5	29.3	82.8	0.16	0.47	0.63	71.3	59.4
	1992	62	20.9	18.8	39.8	0.04	0.33	0.37	71.9	49.0
	1993	58	384.1	20.1	404.1	1.00	0.28	1.28	57.3	143.0
	1994	62	73.4	171.0	244.4	0.12	1.45	1.57	69.5	70.5
	1995	62	106.0	98.7	204.7	0.31	1.03	1.33	70.2	73.0
	1996	58	25.4	40.6	66.1	0.05	0.58	0.63	77.3	47.4

[1]New York Bight: Strata 22-31, 33-35; Delmarva: Strata 10-11, 14-15, 18-19; VA-NC: Strata 6-7. [2]Mean meat weight derived by applying the 1977-1982 USA Mid-Atlantic research survey sea scallop shell height meat weight equation, ln [Meat Weight (g)] = -12.1628 + 3.2539 ln [Shell Height (mm)], (n = 11943, r = 0.98) to the survey shell height frequency distributions.

Table B9. (Continued)

Area	Year	No. of tows	Standardized stratified mean number per tow: Pre-recruit	Recruit	Total	Standardized stratified mean weight (kg) per tow[2]: Pre-recruit	Recruit	Total	Mean shell height	Average meat count
New York Bight	1975	28	39.4	34.7	74.1	0.10	0.62	0.72	75.3	46.9
	1977	101	1.4	56.7	58.1	<0.01	1.03	1.03	98.6	25.6
	1978	116	3.3	52.7	56.0	0.01	1.15	1.16	102.8	21.9
	1979	120	5.3	17.6	22.9	0.01	0.43	0.44	93.6	23.7
	1980	121	15.4	15.2	30.6	0.02	0.36	0.38	75.5	35.7
	1981	117	18.8	19.0	37.8	0.03	0.29	0.32	67.7	53.5
	1982	134	10.9	20.9	31.8	0.02	0.33	0.35	78.4	41.2
	1983	136	11.5	14.0	25.5	0.03	0.29	0.32	80.3	36.6
	1984	142	17.4	18.4	35.8	0.03	0.29	0.32	69.2	51.0
	1985	137	47.4	30.9	78.3	0.10	0.43	0.53	65.6	67.1
	1986	152	53.2	49.3	102.5	0.13	0.65	0.78	69.6	59.9
	1987	154	94.5	46.0	140.5	0.18	0.58	0.76	61.7	83.7
	1988	154	75.9	100.5	176.4	0.11	1.25	1.36	68.6	58.9
	1989	157	168.6	81.8	250.4	0.25	0.90	1.15	56.4	99.1
	1990	148	121.1	92.8	213.9	0.35	0.88	1.23	67.2	78.7
	1991	157	22.2	53.7	75.9	0.06	0.67	0.73	78.3	47.3
	1992	157	17.7	25.3	43.0	0.04	0.37	0.41	75.5	47.4
	1993	146	46.6	24.0	70.6	0.10	0.31	0.41	64.9	77.9
	1994	155	102.1	45.8	147.9	0.12	0.49	0.61	55.6	109.1
	1995	155	57.7	106.1	163.8	0.19	0.97	1.15	73.1	67.0
	1996	143	5.7	49.5	55.2	0.01	0.55	0.56	82.9	44.6
Mid-Atlantic (all areas)	1975	43	38.8	32.6	71.4	0.10	0.59	0.69	75.3	47.2
	1977	112	2.8	55.1	57.9	0.01	1.00	1.01	97.7	25.9
	1978	164	7.8	56.8	64.6	0.02	1.23	1.25	99.4	23.4
	1979	166	9.1	26.2	35.3	0.02	0.52	0.54	86.5	29.8
	1980	167	27.1	19.2	46.3	0.04	0.42	0.46	70.1	45.8
	1981	161	16.1	18.0	34.1	0.02	0.30	0.32	70.1	48.2
	1982	185	10.6	20.3	30.9	0.03	0.34	0.37	80.4	38.1
	1983	193	14.3	14.4	28.7	0.04	0.30	0.34	79.4	37.8
	1984	203	17.6	18.5	36.1	0.02	0.31	0.33	69.5	49.2
	1985	201	51.0	31.5	82.5	0.11	0.43	0.54	64.1	69.8
	1986	224	65.2	54.8	120.0	0.17	0.69	0.86	69.3	63.3
	1987	225	85.7	47.9	133.6	0.17	0.61	0.78	63.6	78.0
	1988	226	74.9	88.3	163.2	0.12	1.12	1.24	68.1	59.9
	1989	229	156.9	83.6	240.5	0.24	0.93	1.17	58.1	93.5
	1990	216	103.2	90.6	193.8	0.29	0.88	1.17	68.2	74.9
	1991	228	28.0	49.0	77.0	0.08	0.63	0.71	76.8	49.4
	1992	229	18.1	24.2	42.3	0.03	0.37	0.40	75.0	47.5
	1993	214	109.9	23.8	133.6	0.28	0.30	0.58	60.7	104.5
	1994	227	95.8	69.6	165.4	0.11	0.67	0.80	59.6	94.2
	1995	227	66.4	103.5	170.0	0.21	0.97	1.17	72.4	97.8
	1996	211	9.6	47.3	56.9	0.02	0.55	0.57	81.5	45.4

[1]New York Bight: Strata 22-31, 33-35; Delmarva: Strata 10-11, 14-15, 18-19; VA-NC: Strata 6-7. [2]Mean meat weight derived by applying the 1977-1982 USA Mid-Atlantic research survey sea scallop shell height meat weight equation, ln [Meat Weight (g)] = -12.1628 + 3.2539 ln [Shell Height (mm)], (n = 11943, r = 0.98) to the survey shell height frequency distributions.

Table B10. Post-stratified estimates of mean weight per tow in the open and closed areas of Georges Bank for non-overlapping length cohorts. The von Bertalanffy growth equation and the meat weight - shell height regression were used to compute expected ratios for these length cohorts.

Area	Min length	Max length	Survey in 1995 (g/tow)	Survey in 1996 (g/tow)	Observed weight ratio wt ('96) wt ('95)	Theoretical ratio when M = 0.1
Closed	40	79	312	412		
	80	109	220	1,083	3.48	3.04
	110	129	181	598	2.71	1.66
Open	40	79	305	229		
	80	109	223	402	1.32	3.04
	110	129	172	79	0.35	1.66

Table B11. Summary of commercial landings and survey indices input into the modified DeLury model. Survey indices have been adjusted by selectivity of survey lined gear and vulnerability of fishery dredge.

	Commercial landings						Adjusted survey indices (no./tow)		
	Meat weight (mt)		Mean weight[1] (g)		Catch number[1] (x10^6)				
Year	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Recruited	Fully-recruited	Total
Georges Bank									
1982	3,012	3,309	22.117	21.496	136.185	153.938	124.287	45.614	169.901
1983	2,119	2,164	23.674	27.264	89.507	79.372	47.706	39.223	86.929
1984	1,308	1,734	27.650	27.200	47.305	63.750	166.026	33.529	199.555
1985	825	2,070	22.887	25.811	36.047	80.198	141.468	77.853	219.321
1986	1,995	2,440	18.787	21.109	106.192	115.589	182.426	128.108	310.535
1987	1,916	2,934	16.086	20.826	119.113	140.878	153.327	78.316	231.643
1988	2,743	3,312	20.880	21.049	131.371	157.351	104.748	65.576	170.324
1989	2,388	3,276	23.772	23.056	100.455	142.092	-	-	-
1990	3,633	6,352	17.013	17.437	213.544	364.287	279.706	104.504	384.211
1991	5,348	3,963	16.696	20.852	320.318	190.058	270.642	50.322	320.964
1992	4,388	3,849	16.537	16.802	265.344	229.080	198.866	48.696	247.562
1993	2,275	1,380	19.603	24.033	116.054	57.421	25.278	15.133	40.411
1994	628	508	18.679	19.749	33.647	25.746	27.336	20.507	47.843
1995	139	868	19.001	21.231	7.292	40.870	100.787	16.178	116.964
1996	662	n/a	18.543	n/a	35.694	n/a	100.737	70.126	170.863
Mid-Atlantic									
1982	775	836	23.127	29.793	33.506	28.068	17.211	23.446	40.657
1983	1,697	1,411	24.549	27.385	69.116	51.543	19.231	17.972	37.203
1984	2,291	1,382	22.800	24.129	100.498	57.262	22.022	22.826	44.848
1985	2,157	1,119	22.803	26.975	94.587	41.499	68.964	33.655	102.619
1986	1,807	1,551	21.267	21.084	84.966	73.564	93.278	60.509	153.787
1987	4,376	3,429	18.474	19.932	236.867	172.011	107.123	56.020	163.143
1988	3,648	2,529	20.344	26.041	179.315	97.122	106.575	98.020	204.595
1989	5,815	2,159	21.104	20.837	275.532	103.639	203.034	84.472	287.506
1990	4,789	1,646	17.462	16.182	274.238	101.715	167.683	83.669	251.352
1991	4,601	2,408	23.050	27.994	199.616	86.027	48.088	53.691	101.779
1992[2]	2,659	2,296	20.772	21.178	128.022	108.415	25.818	28.327	54.144
1993[2]	1,451	1,327	24.539	24.770	59.139	53.563	136.181	25.347	161.529
1994[2,3]	2,959	2,914	16.730	14.097	176.845	206.699	132.465	64.945	197.410
1995[2,3]	4,226	1,869	16.419	22.301	257.367	83.791	171.759	42.146	213.906
1996[2,3]	2,985	n/a	12.773	n/a	233.714	n/a	24.468	52.565	77.032

[1]Mean meat weight derived by applying the 1977-1982 USA research survey sea scallop shell height - meat weight equations to the shell heightfrequency distributions from commercial fisheries. Georges Bank region: ln[Meat Weight (g)] = -11.7656 + 3.1693 ln[Shell Height (mm)], (n = 5863, r = 0.98); Mid-Atlantic region: ln[Meat Weight (g)] = -12.1628 + 3.2539 ln[Shell Height (mm)], (n = 11943, r = 0.98). [2]Shell height frequency distributions were derived from the combination of shells collected from port sampling and NEFSC sea scallop sea sampling to calculate mean wieight and catch number. [3]Landings are estimated preliminarily from Vessel Trip Reports and Dealer Logs.

Table B12. Comparison of alternative estimators of exploitation rates for Georges Bank and Mid-Atlantic regions, 1982-1996. Minimum swept-area biomass estimates are computed for two levels of gear efficiency. Swept-area F is estimated as landings divided by mean biomass between adjacent years. Relative exploitation rate is defined as the ratio of catch in biomass in year t to the average weight per tow between the start of year t and t+1. Average exploitable biomass is estimated as the average weight of the sum of grams per tow of recruits and full recruits in year t and year t+1.

			Survey				Swept-area biomass (mt) w/efficiency		Estimated fishing mortality rate						
			Number/tow		g/tow				Swept-area based				DeLury bootstrap estimates		
Region	Survey year	Landings (mt)	Rec	Fully-rec	Rec	Fully-rec	0.5	1	0.5	1	Relative F	Survey Index	10%	50%	90%
Georges Bank	1982	5,428	124.287	45.614	351.7	737.3	14,104	7,052	0.29	0.59	5.71	1.37	0.92	1.14	1.38
	1983	3,472	47.706	39.223	146.5	665.3	10,515	5,257	0.24	0.48	4.28	0.85	0.71	0.94	1.15
	1984	2,559	166.026	33.529	210.2	600.4	10,499	5,249	0.15	0.31	2.15	0.84	0.23	0.41	0.62
	1985	4,065	141.468	77.853	628.3	939.7	20,310	10,155	0.13	0.26	2.13	0.44	0.41	0.58	0.77
	1986	4,356	182.426	128.108	529.9	1,726.8	29,229	14,614	0.12	0.24	2.29	1.28	0.55	0.77	0.95
	1987	5,677	153.327	78.316	438.5	1,108.0	20,030	10,015	0.22	0.44	4.03	1.16	0.75	0.99	1.20
	1988	5,700	104.748	65.576	373.2	898.1	16,466	8,233	0.25	0.49	4.01	0.72	1.35	1.74	2.08
	1989[1]	6,909	202.106	74.680	553.9	1,016.5	20,339	10,170	0.24	0.48	3.79	0.87	0.82	1.12	1.40
	1990	11,700	279.706	104.504	795.3	1,279.5	26,874	13,437	0.37	0.73	6.76	1.93	1.49	1.82	2.25
	1991	8,351	270.642	50.322	608.5	780.2	17,987	8,994	0.38	0.77	6.09	1.79	1.19	1.56	1.83
	1992	6,124	198.866	48.696	773.9	577.7	17,506	8,753	0.32	0.64	7.19	2.69	1.60	2.02	2.41
	1993	2,008	25.278	15.133	100.8	251.8	4,567	2,283	0.30	0.61	5.29	0.58	0.90	1.14	1.43
	1994	647	27.336	20.507	88.1	318.0	5,260	2,630	0.09	0.19	1.59	0.98	0.36	0.53	0.70
	1995	1,530	100.787	16.178	165.2	243.5	5,293	2,647	0.13	0.25	1.71	0.41	0.18	0.37	0.58
	1996	-	100.737	70.126	319.8	1,064.2	17,926	8,963	-	-	-	-	-	-	-
Mid-Atlantic	1982	2,533	17.211	23.446	65.8	451.6	7,574	3,787	0.24	0.48	5.08	0.72	0.46	0.65	0.83
	1983	3,703	19.231	17.972	62.6	416.9	7,020	3,510	0.37	0.74	7.83	0.39	0.74	0.94	1.16
	1984	3,539	22.022	22.826	52.7	413.6	6,825	3,413	0.33	0.66	5.89	0.19	0.71	0.92	1.14
	1985	2,926	68.964	33.655	205.2	531.0	10,777	5,389	0.17	0.34	3.04	0.43	0.28	0.43	0.59
	1986	5,927	93.278	60.509	321.0	865.5	17,369	8,684	0.26	0.51	5.28	0.91	0.62	0.80	1.00
	1987	7,076	107.123	56.02	281.3	775.7	15,474	7,737	0.27	0.55	5.08	0.41	0.53	0.69	0.85
	1988	8,344	106.575	98.02	321.2	1,406.1	25,286	12,643	0.25	0.50	5.01	0.78	0.62	0.81	1.01
	1989	6,948	203.034	84.472	514.5	1,086.0	23,429	11,714	0.23	0.46	4.32	1.13	0.64	0.83	0.97
	1990	6,247	167.683	83.669	658.3	954.4	23,607	11,804	0.21	0.43	4.80	1.44	0.68	0.80	0.96
	1991	5,067	48.088	53.691	198.9	788.9	14,460	7,230	0.28	0.56	6.54	1.18	0.70	0.85	1.00
	1992	3,747	25.818	28.327	84.1	478.4	8,235	4,117	0.34	0.68	5.70	0.66	0.82	1.04	1.33
	1993	4,286	136.181	25.347	379.0	373.6	11,018	5,509	0.26	0.53	4.64	0.81	0.45	0.63	0.81
	1994	7,140	132.465	64.945	368.9	724.0	15,998	7,999	0.37	0.75	6.78	1.44	1.07	1.31	1.55
	1995	4,854	171.759	42.146	580.2	431.7	14,814	7,407	0.25	0.49	5.35	1.30	0.58	0.79	0.99
	1996	-	24.468	52.565	128.4	673.3	11,735	5,868	-	-	-	-	-	-	-

[1]Survey indices = average of indices in (1987, 1988, 1990, 1991). Area of Georges Bank (nm^2) = 7,456, Area of Mid-Atlantic (nm^2) = 8,427, Area swept by tow (nm^2) = 0.00115.

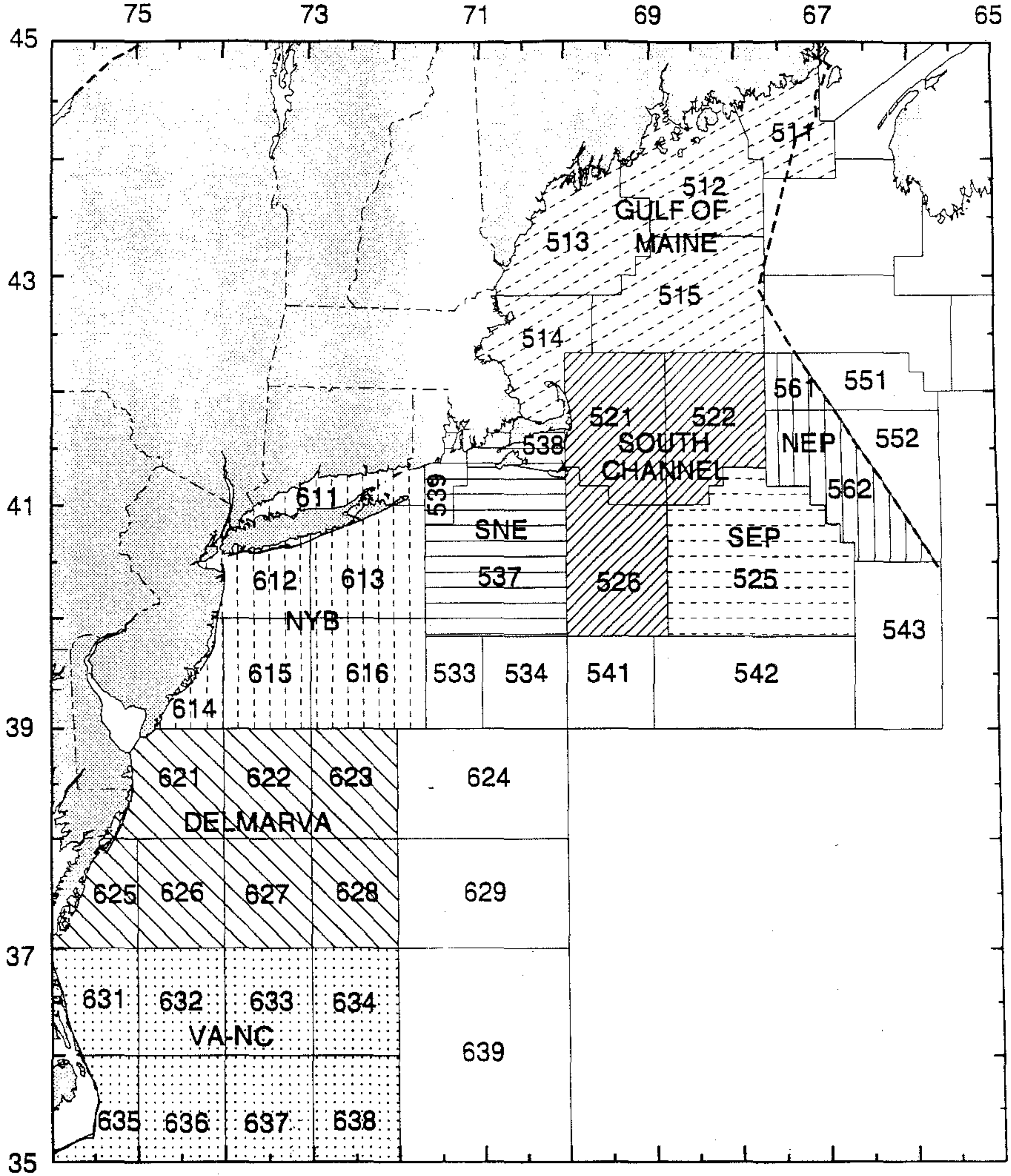


Figure B1. NEFSC statistical reporting areas and stock areas for sea scallops. Gulf of Maine = 511-515, Great South Channel = 521, 522, and 526, Northern Edge and Peak = 561 and 562, Southeast Part = 525, Southern New England = 537-539, New York Bight = 611-616, Delmarva = 621-623, 625-628, and Virginia-North Carolina = 631-638.

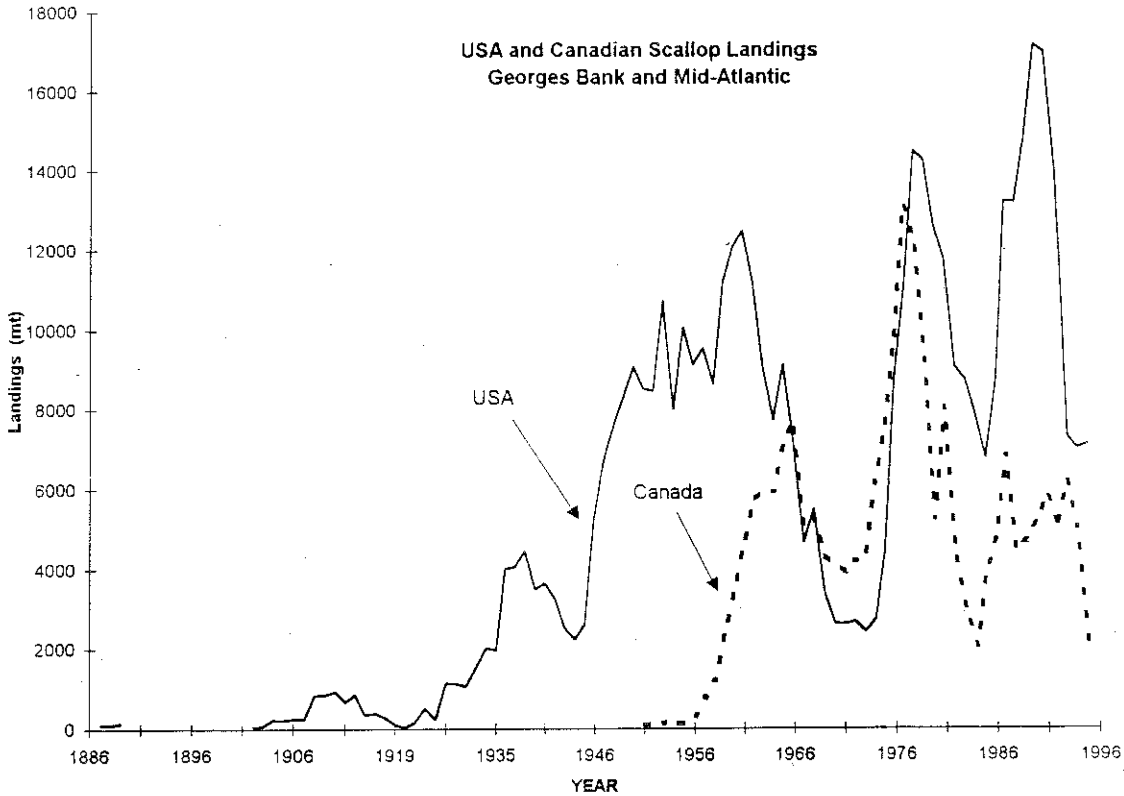


Figure B2. United States and Canadian sea scallop landings (mt of meats) from the Northwest Atlantic (NAFO Subareas 5 and 6), 1887-1995.

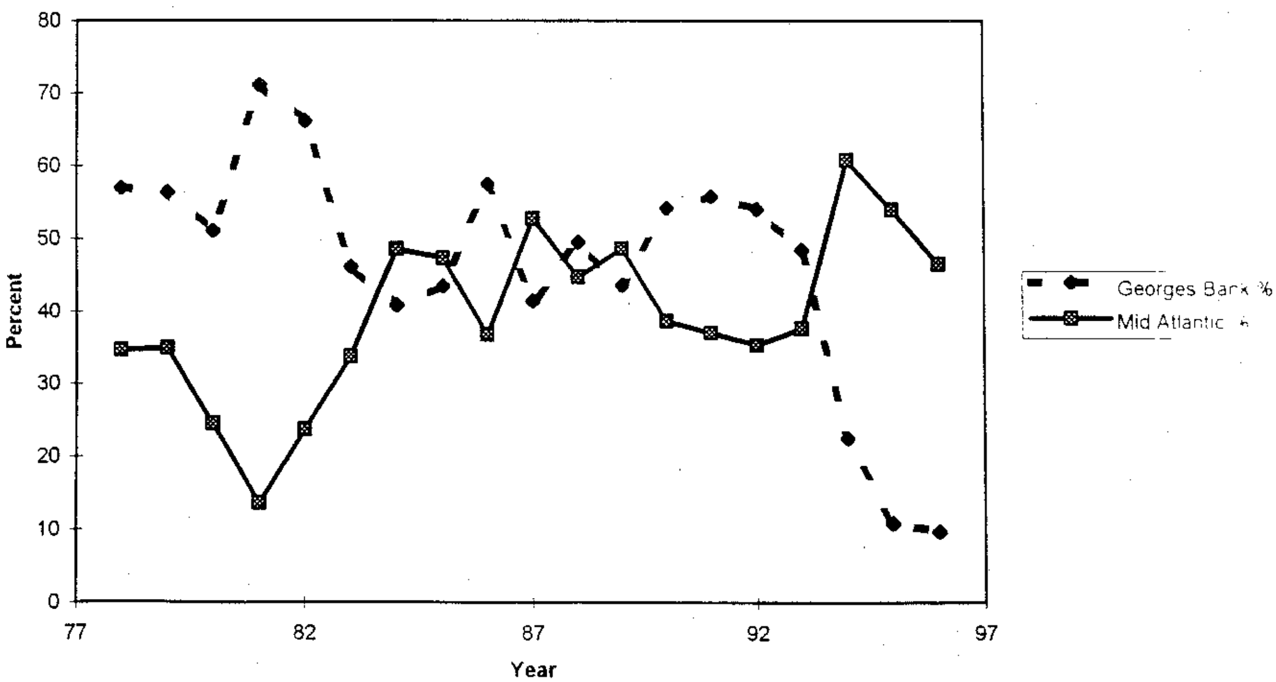


Figure B3. Percent of total vessel trips; Georges Bank vs Mid-Atlantic.

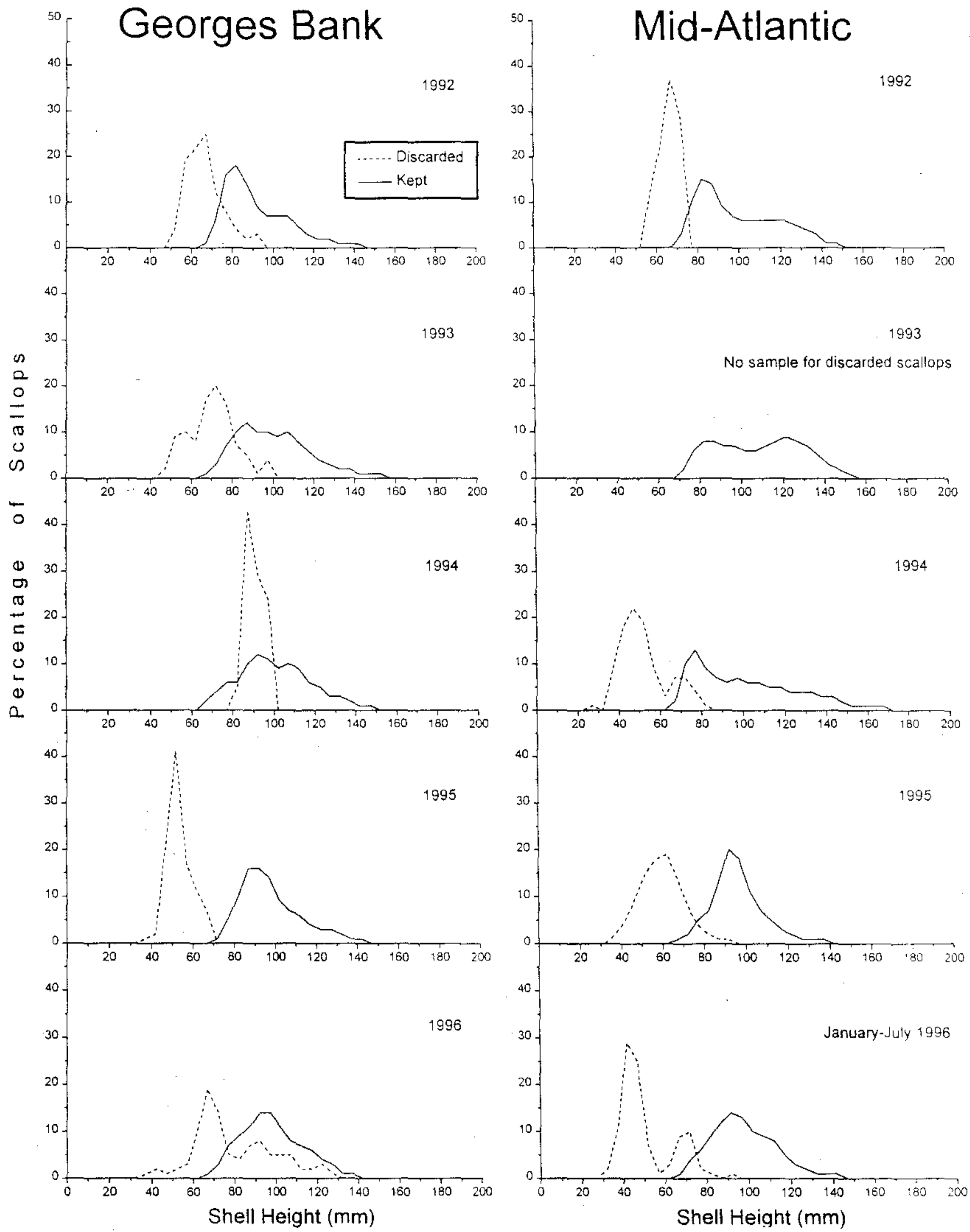


Figure B4. Shell height frequency distributions of discarded and kept sea scallops on Georges Bank and in the Mid-Atlantic region, 1992-1996.

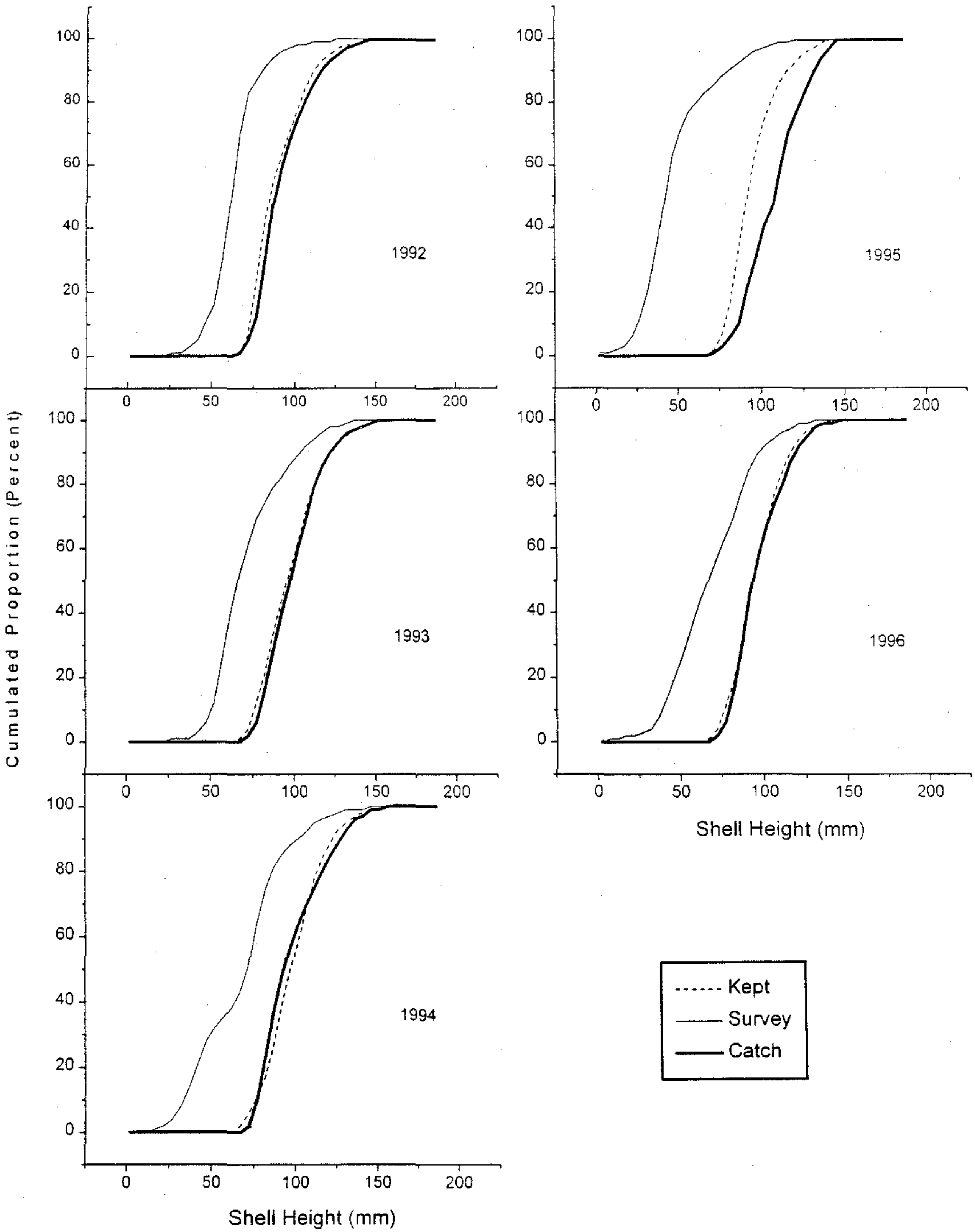


Figure B5. Comparison of cumulative shell height frequency distributions of discarded and kept scallops collected from sea sampling program, catch from NEFSC research vessel surveys, and shells collected from port sampling in the Georges Bank region, 1992-1996.

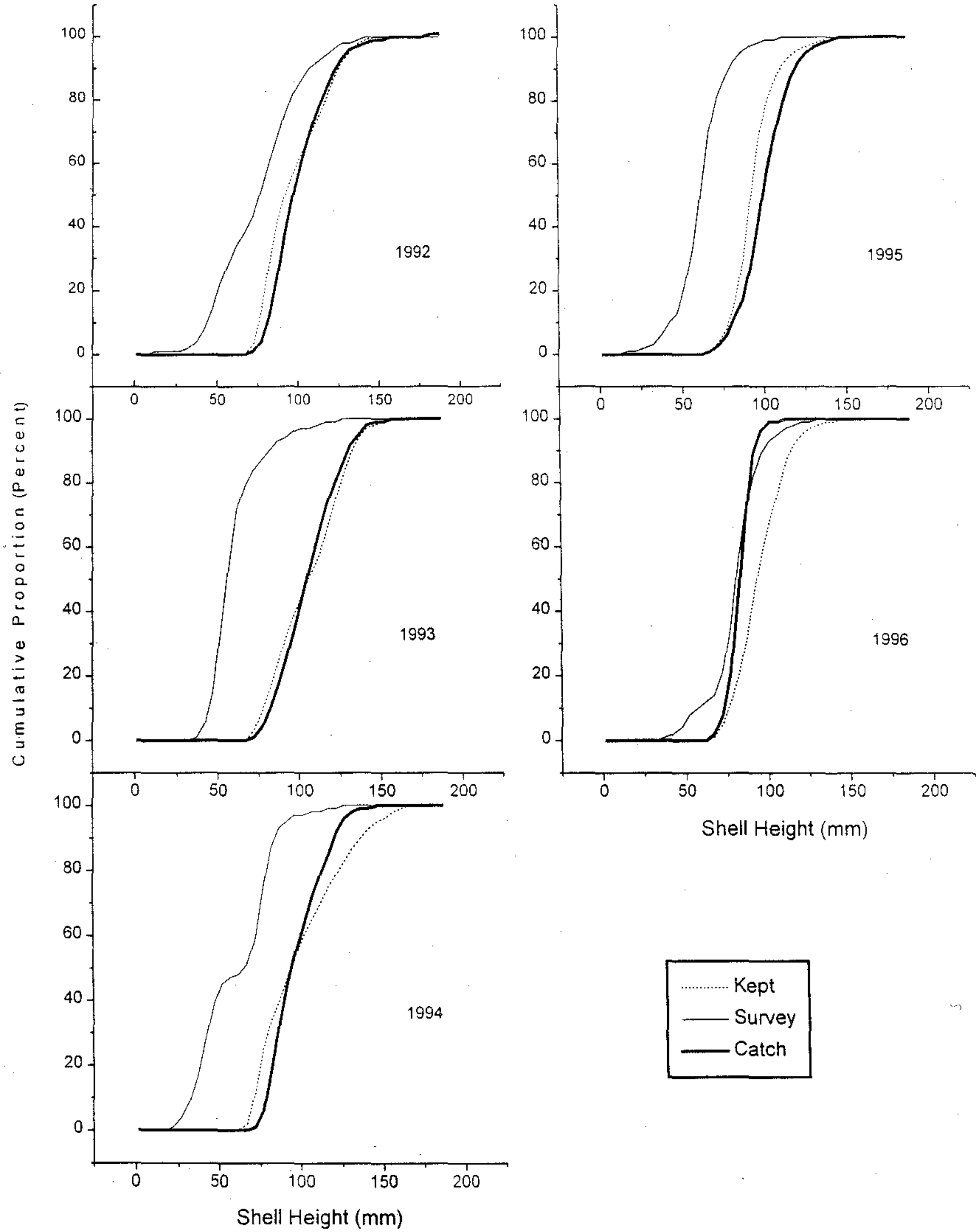


Figure B6. Comparison of cumulative shell height frequency distributions of discarded and kept scallops collected from sea sampling program, catch from NEFSC research vessel surveys, and shells collected from port sampling in the Mid-Atlantic region, 1992-1996.

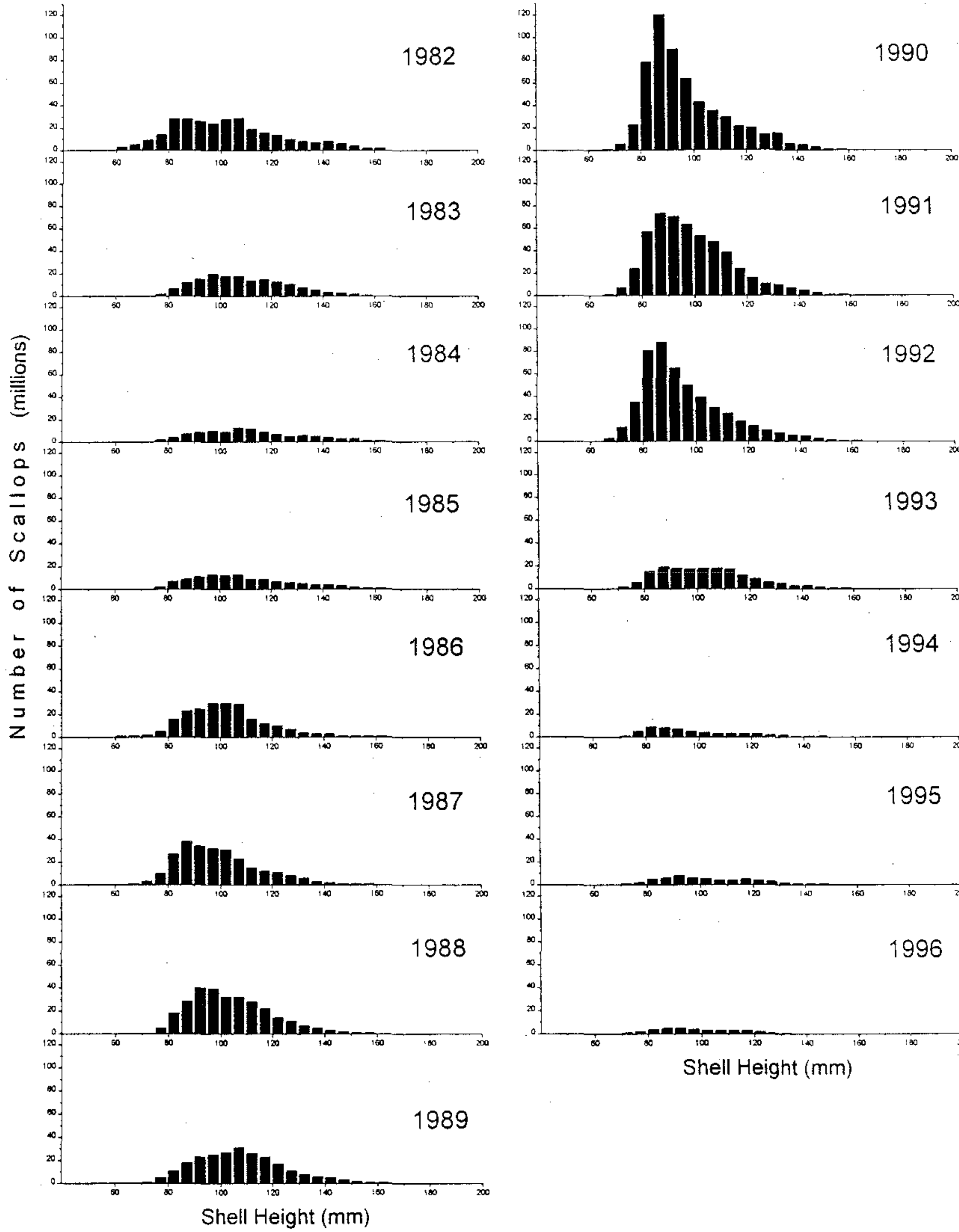


Figure B7. Shell height frequency distributions of commercial landings on Georges Bank, 1982-1996. The 1992-1996 distributions are calculated by combining shell samples from NEFSC port and sea samples.

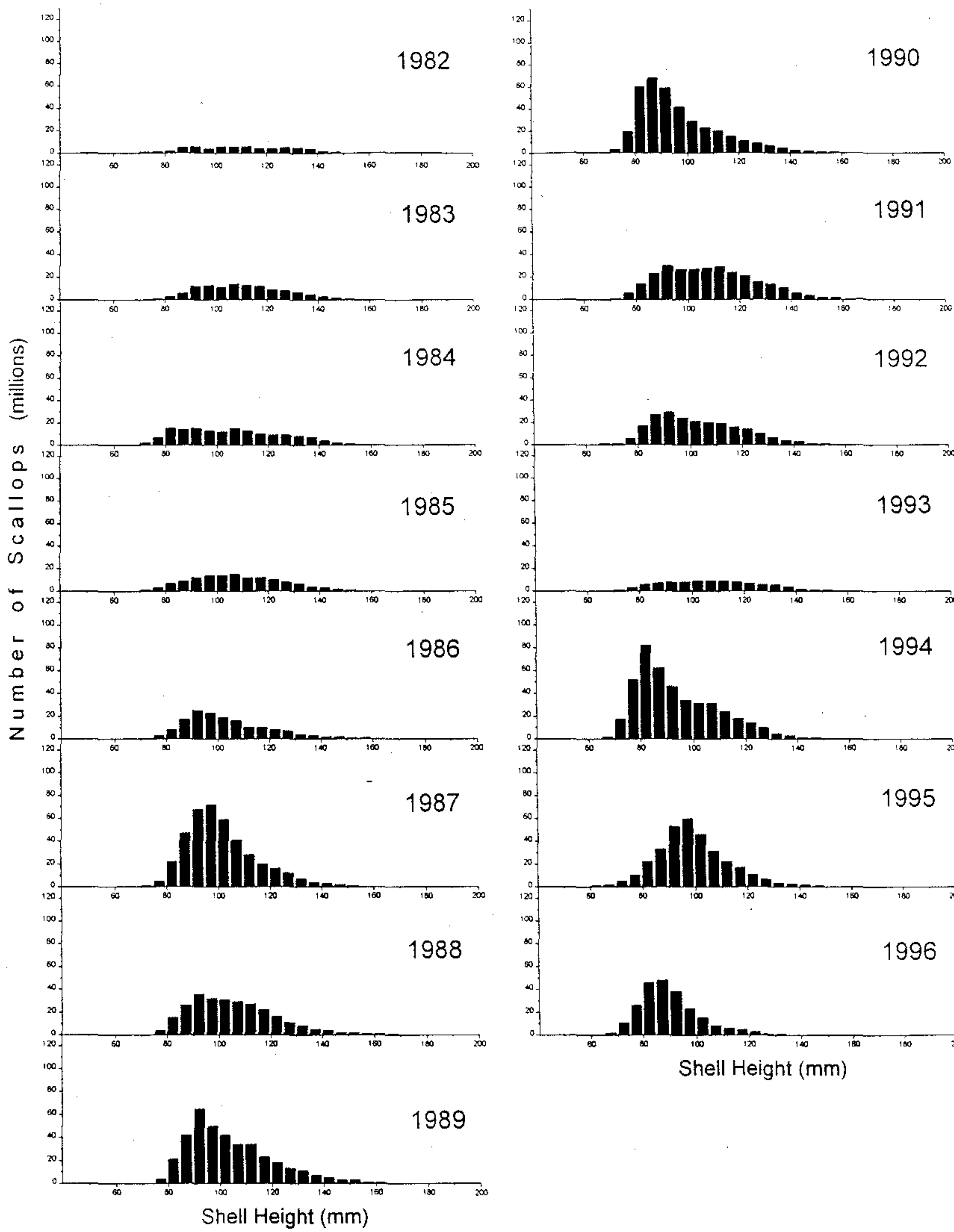


Figure B8. Shell height frequency distributions of commercial landings in the Mid-Atlantic region, 1982-1996. The 1992-1996 distributions are calculated by combining shell samples from NEFSC port and sea samples.

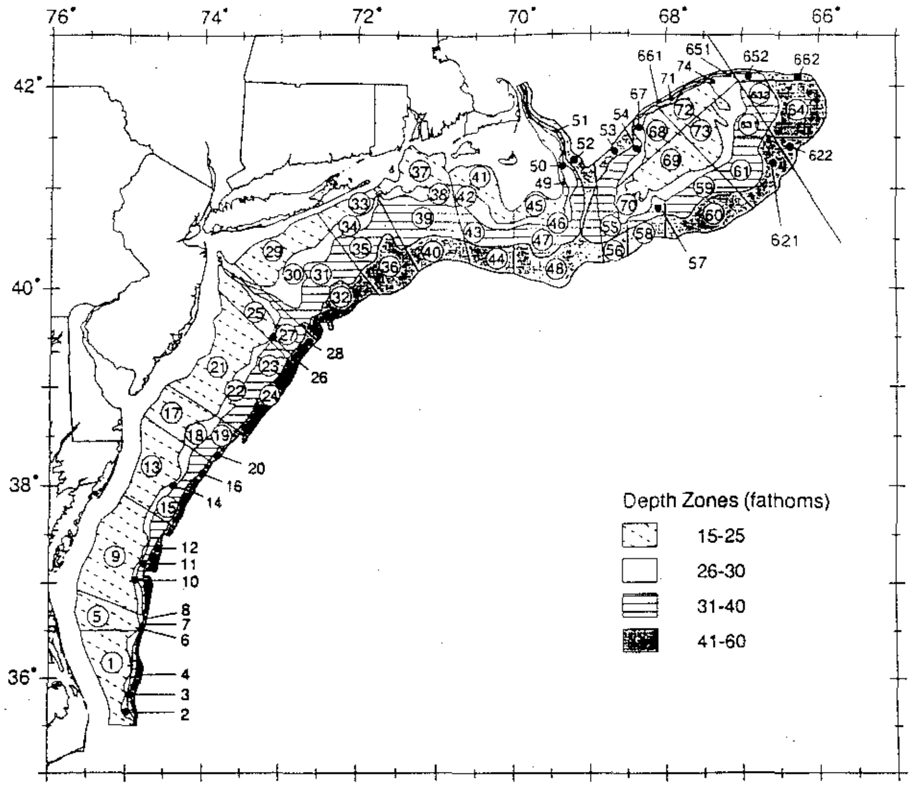


Figure B9. Sampling strata for the NEFSC sea scallop research survey.

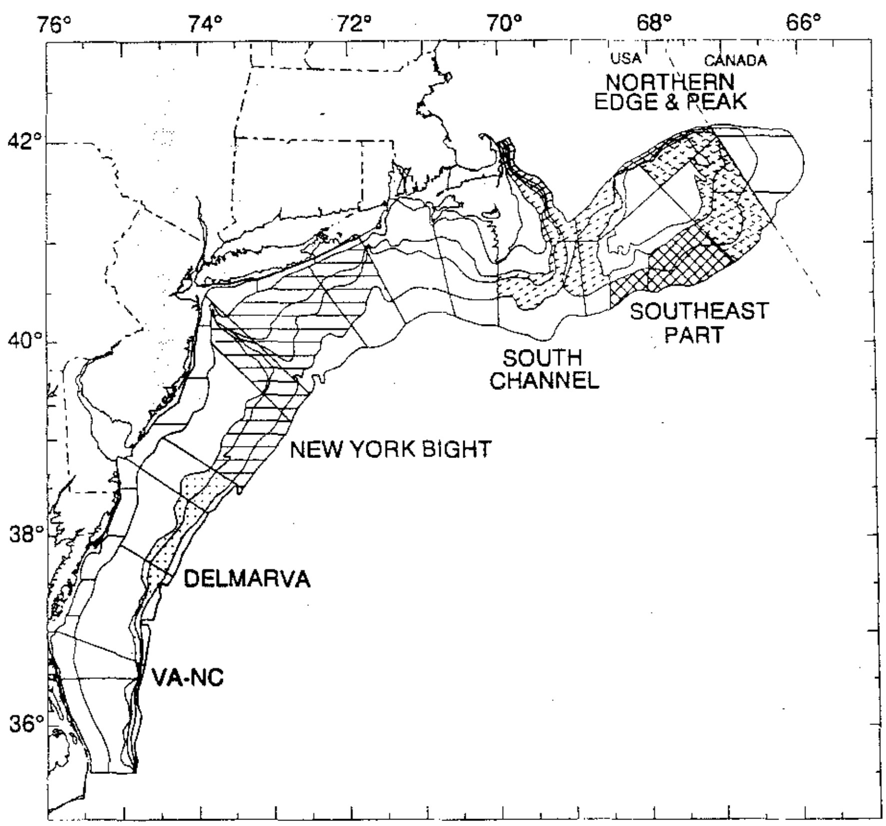


Figure B10. NEFSC sea scallop research survey sub-regions.

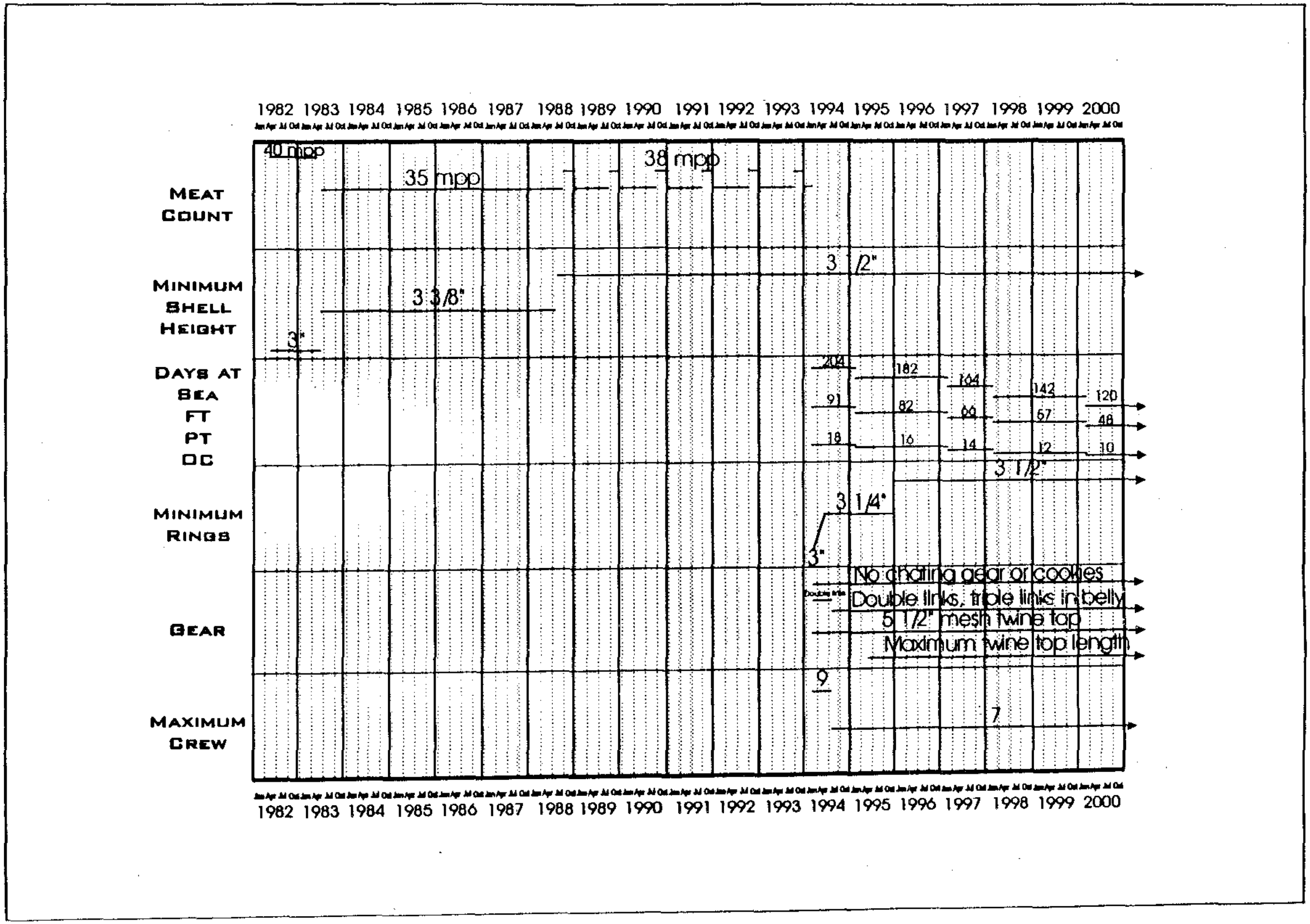


Figure B11. Scallop management chronology of major regulations implemented since 1982 and planned through 2000. Abbreviations: mpp = meats per pound, FT - full-time vessels, PT = part-time vessels, and OC = occasional vessels.

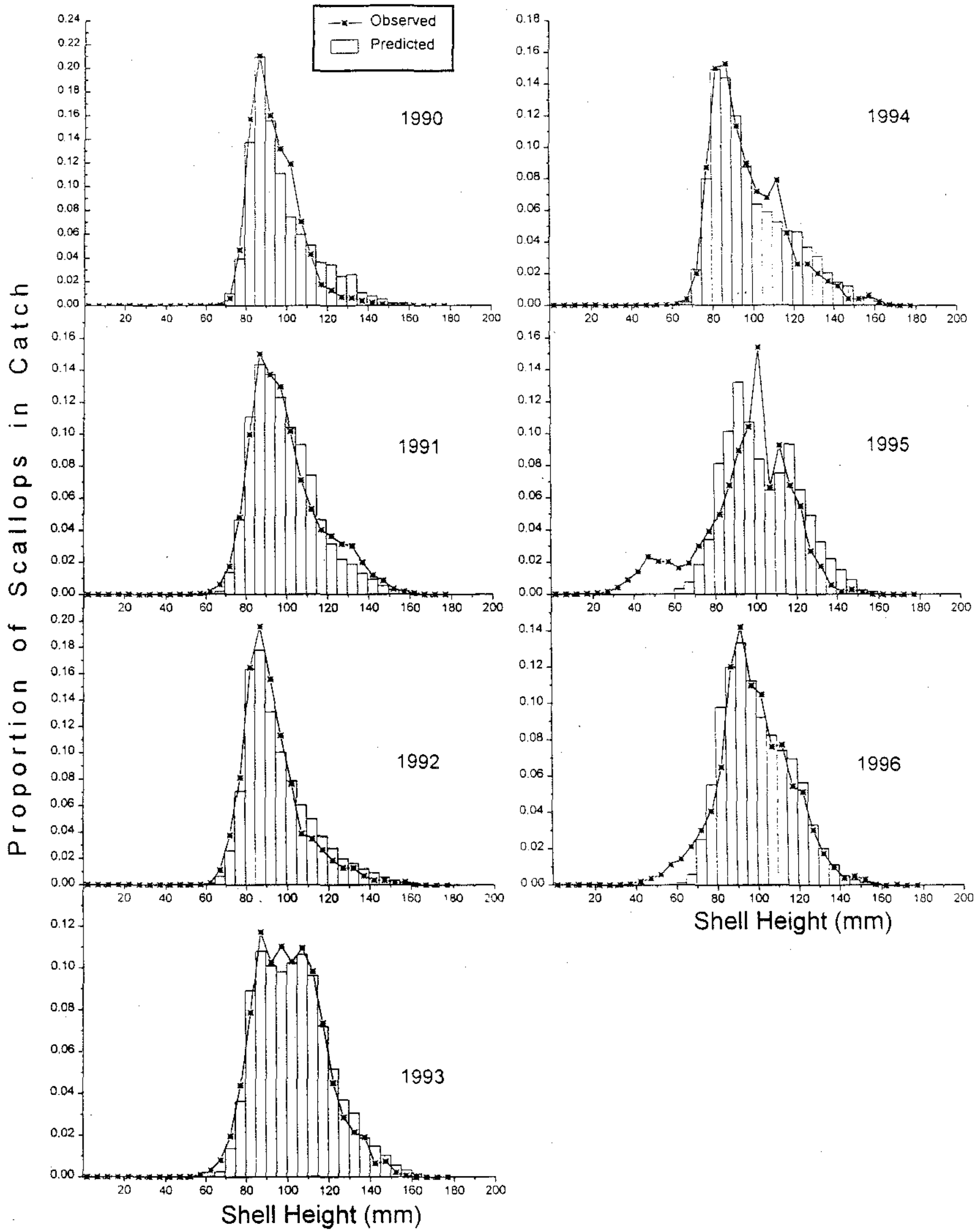


Figure B12. Observed and predicted proportion of scallops in the catch from Georges Bank, 1990-1996.

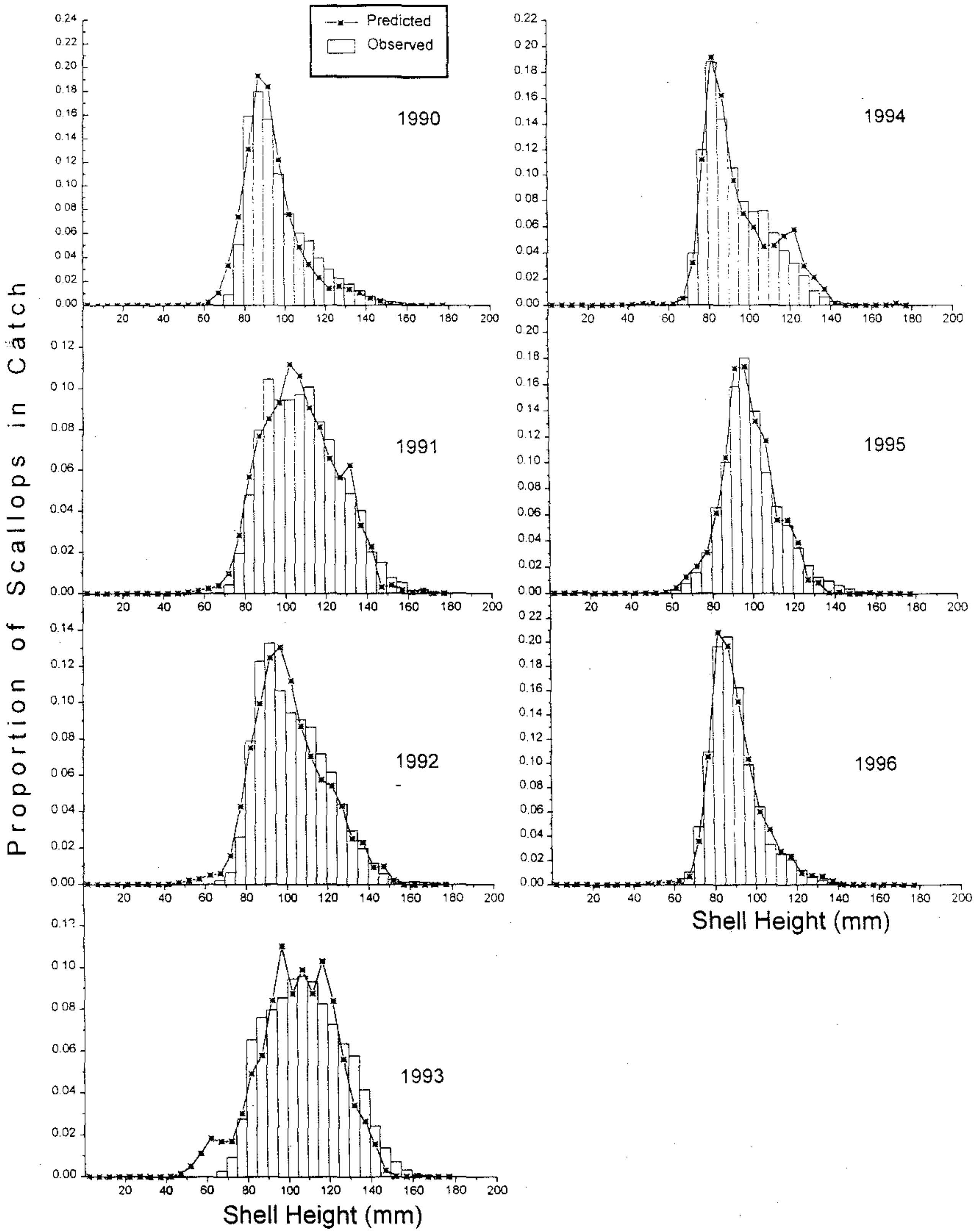


Figure B13. Observed and predicted proportion of scallops in the catch from the Mid-Atlantic region, 1990-1996.

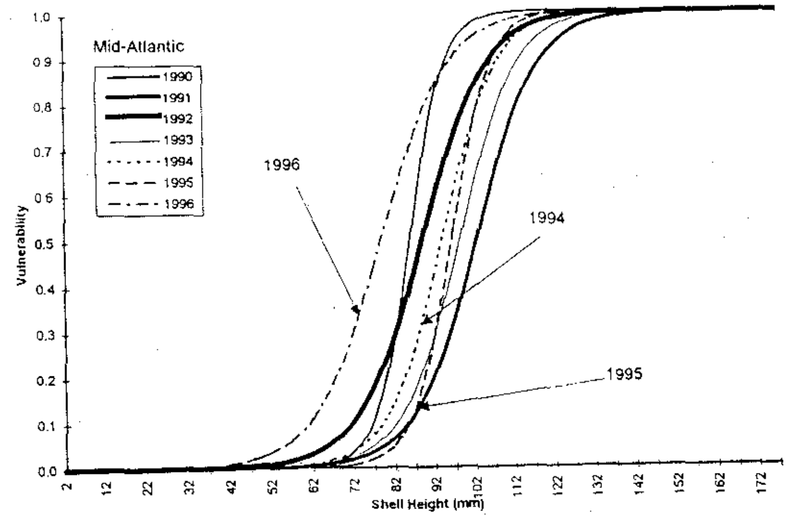


Figure B14. Vulnerability of sea scallops to commercial fisheries using scallop dredges in the Mid-Atlantic region, relative to the NEFSC sea scallop research surveys, 1990-1996.

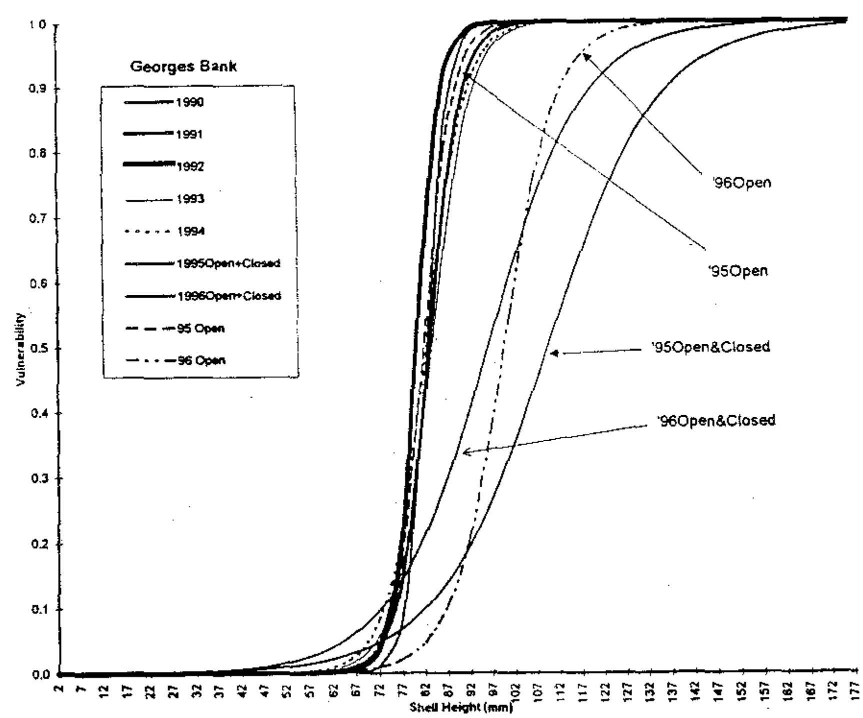


Figure B15. Vulnerability of sea scallops to commercial fisheries using scallop dredges in the Georges Bank region, relative to the NEFSC sea scallop research surveys, 1990-1996.

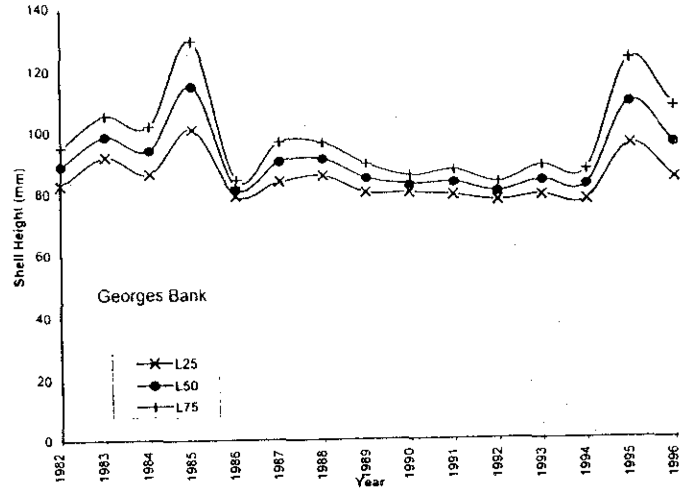


Figure B16. Estimated L_{25}, L_{50}, and L_{75} of landed scallops from Georges Bank, 1982-1996.

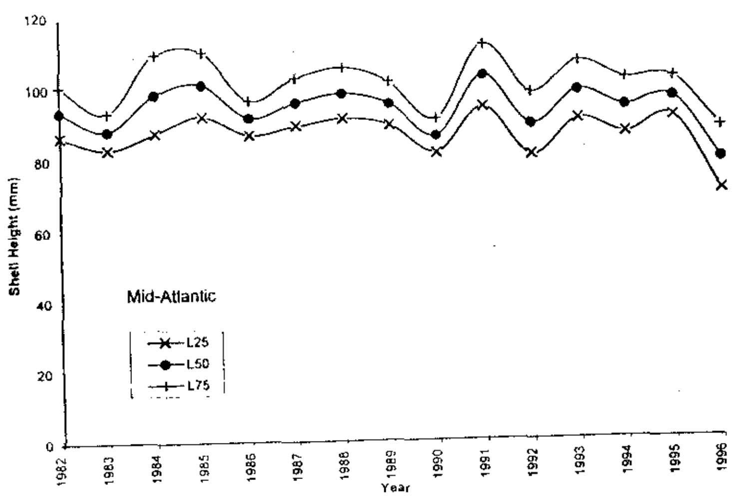


Figure B17. Estimated L_{25}, L_{50}, and L_{75} of landed scallops from the Mid-Atlantic region, 1982-1996.

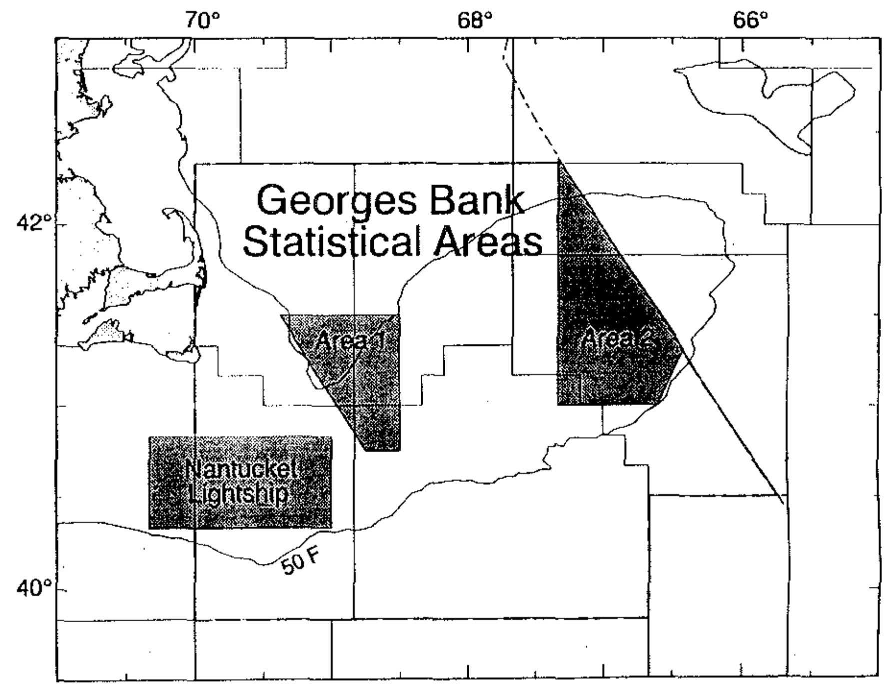


Figure B18. Areas closed to scalloping (groundfish closed areas) in the Georges Bank and Southern New England area.

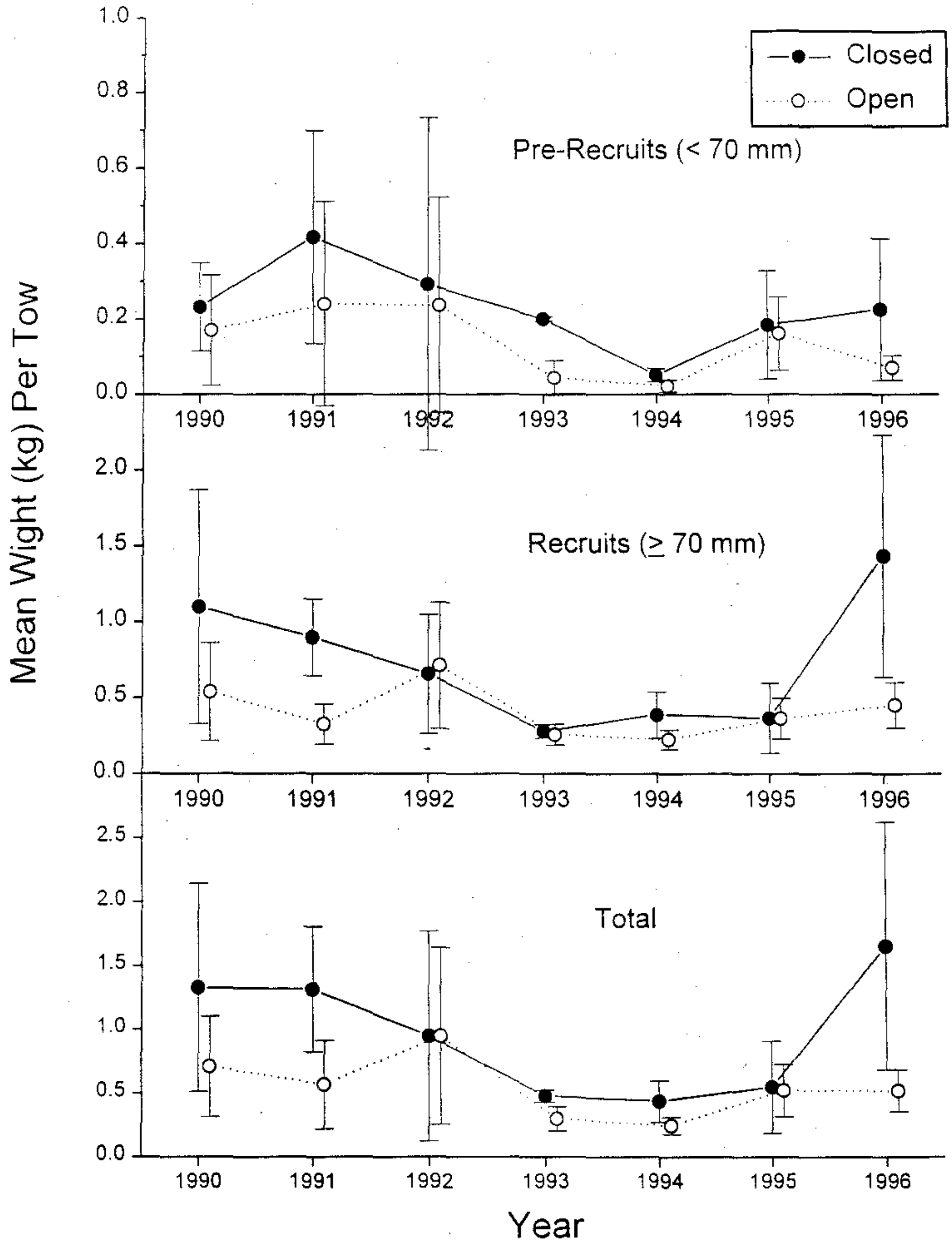


Figure B19. Comparison of post-stratified survey mean weight (kg) per tow from open and closed areas on Georges Bank, 1990-1996. Vertical lines represent 95% confidence intervals.

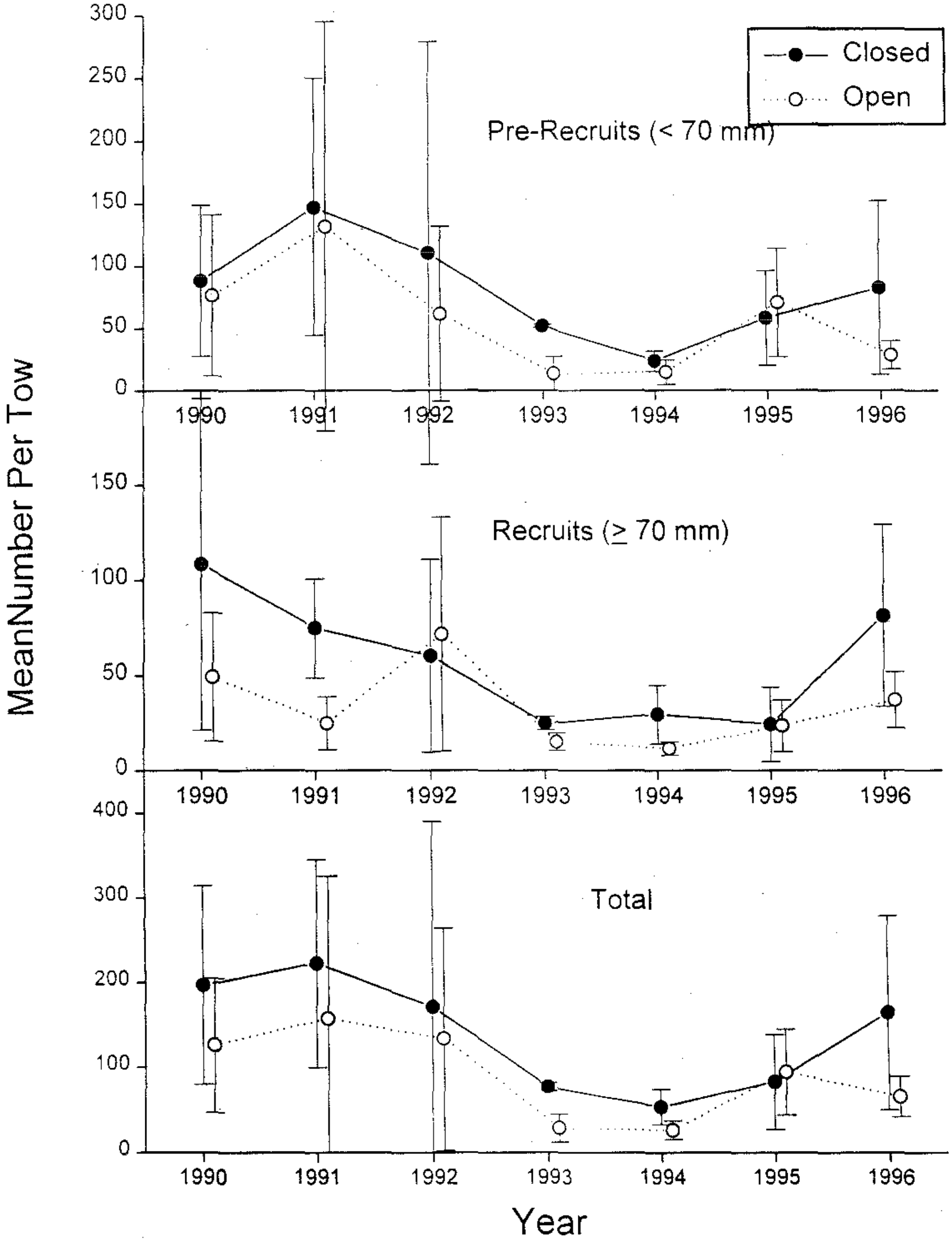


Figure B20. Comparison of post-stratified survey mean number per tow from open and closed areas on Georges Bank, 1990-1996. Vertical lines represent 95% confidence intervals.

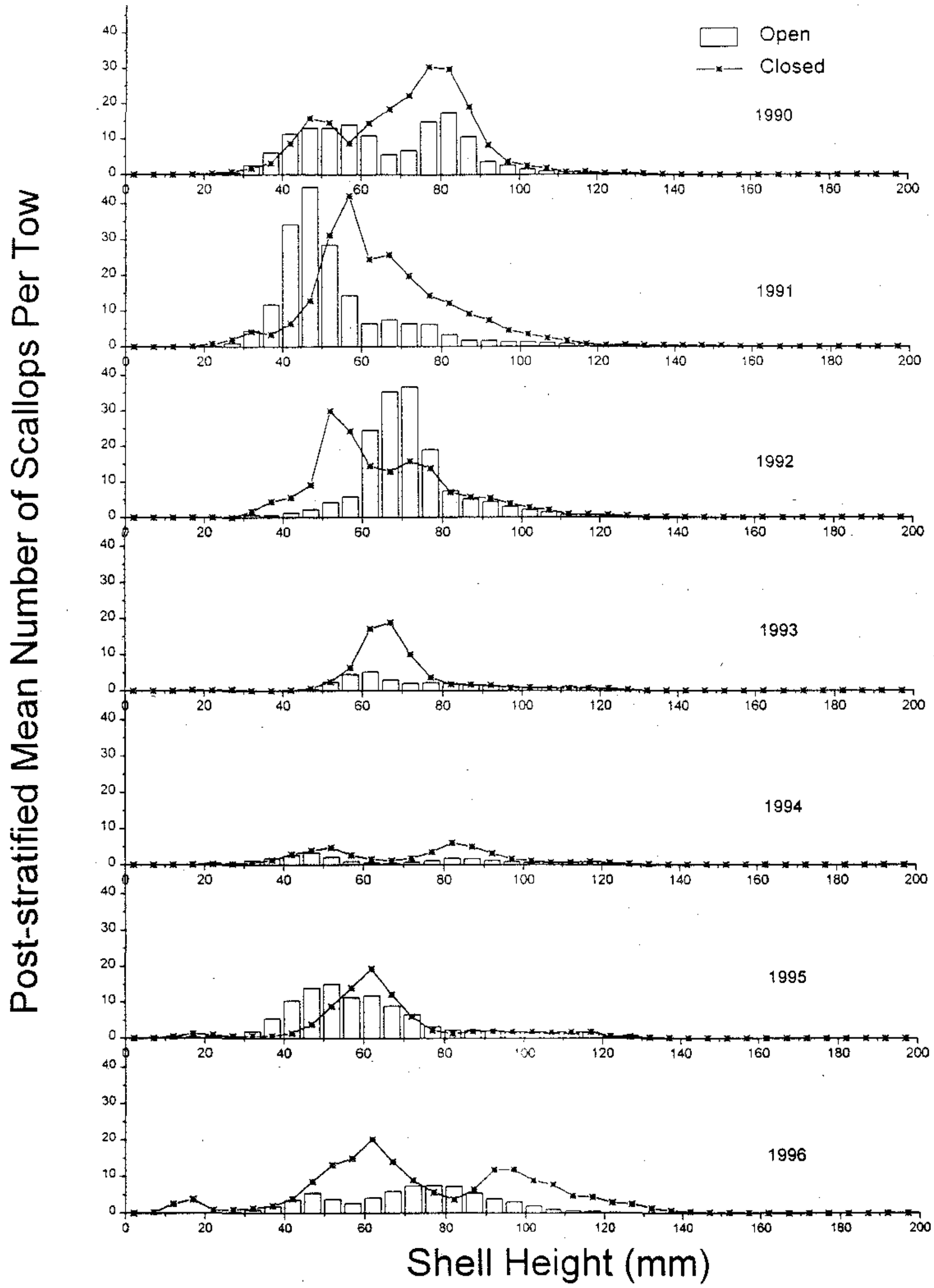
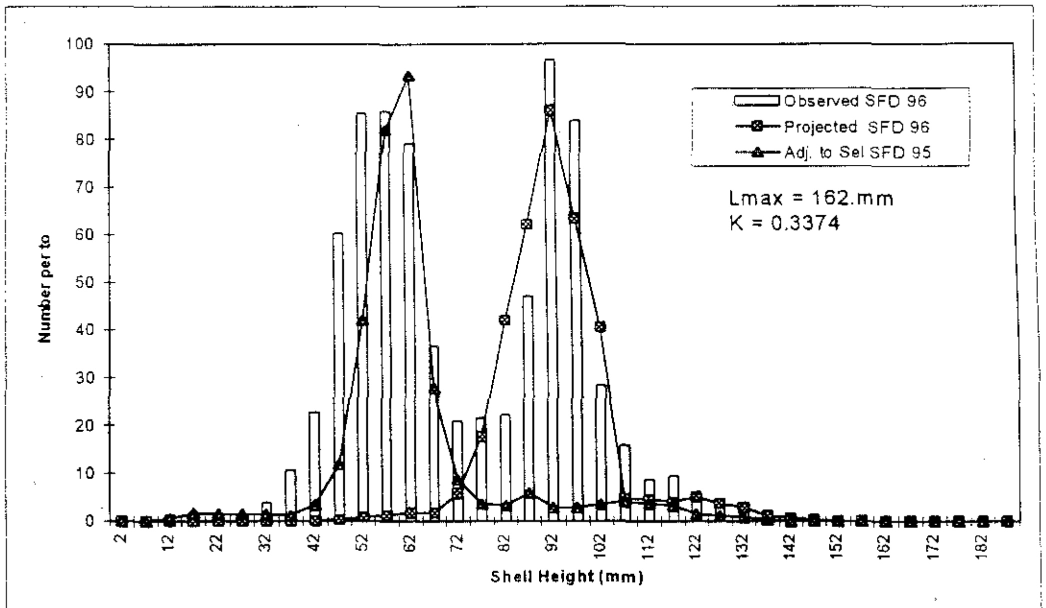


Figure B21. Shell height frequency distribution of sea scallops collected by NEFSC sea scallop research surveys in the closed and open areas on Georges Bank, 1990-1996.



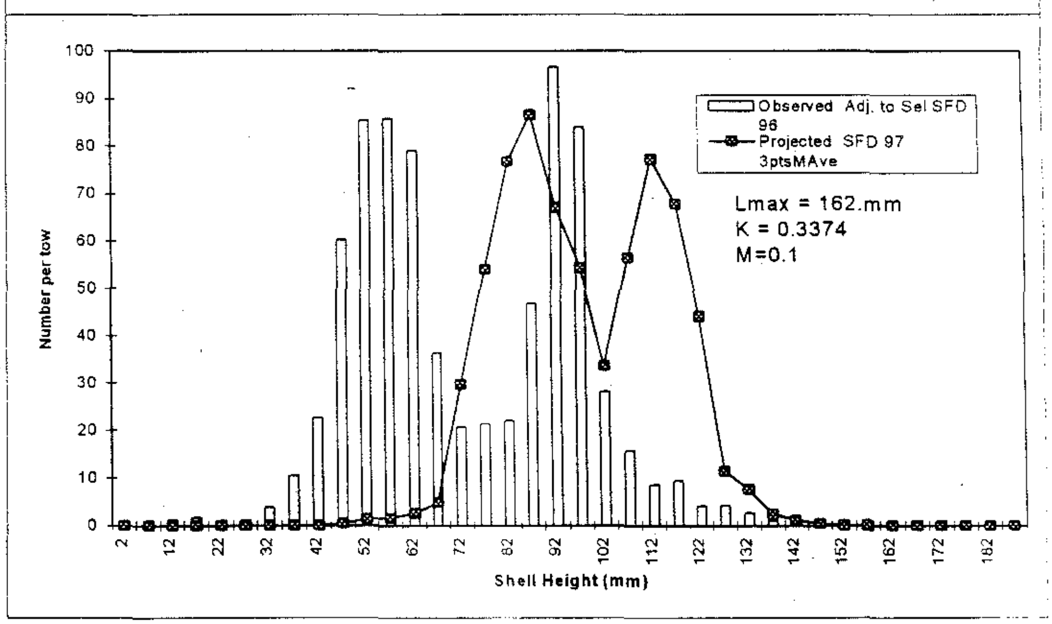


Figure B22. Observed and projected 1996 survey length frequency distributions (top) and 1996 observed, adjusted and 1997 projected survey length frequency distributions (bottom).

Survey Selectivity

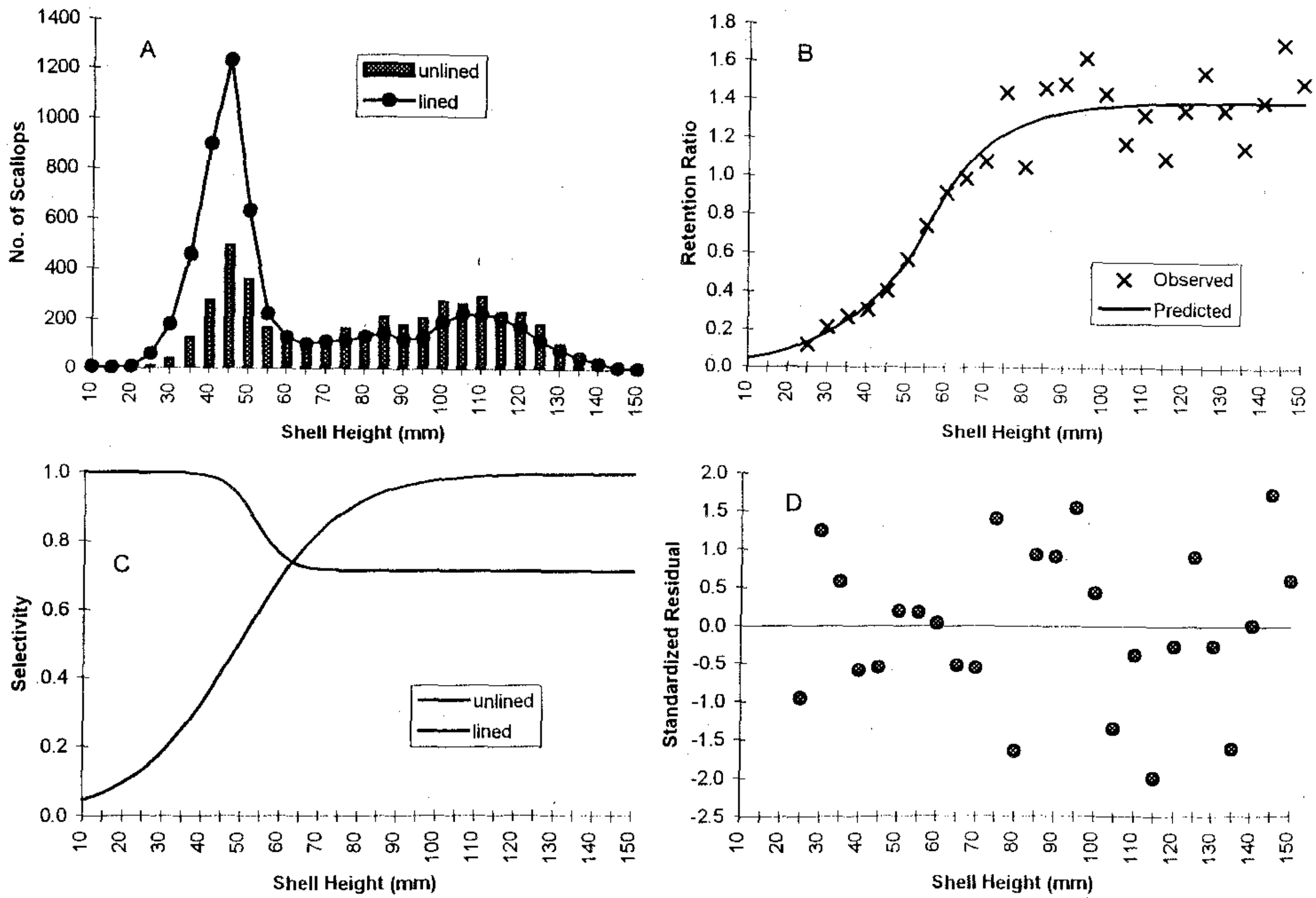


Figure B23. A: Size frequency distributions of lined and unlined dredges. **B:** Observed (x) and estimated (curve) retention ratio between the lined and unlined dredges. **C:** The estimated selectivity curve for lined and unlined dredges. **D:** Plot of standardized log-transformed residuals between observed and estimated retention ratios.

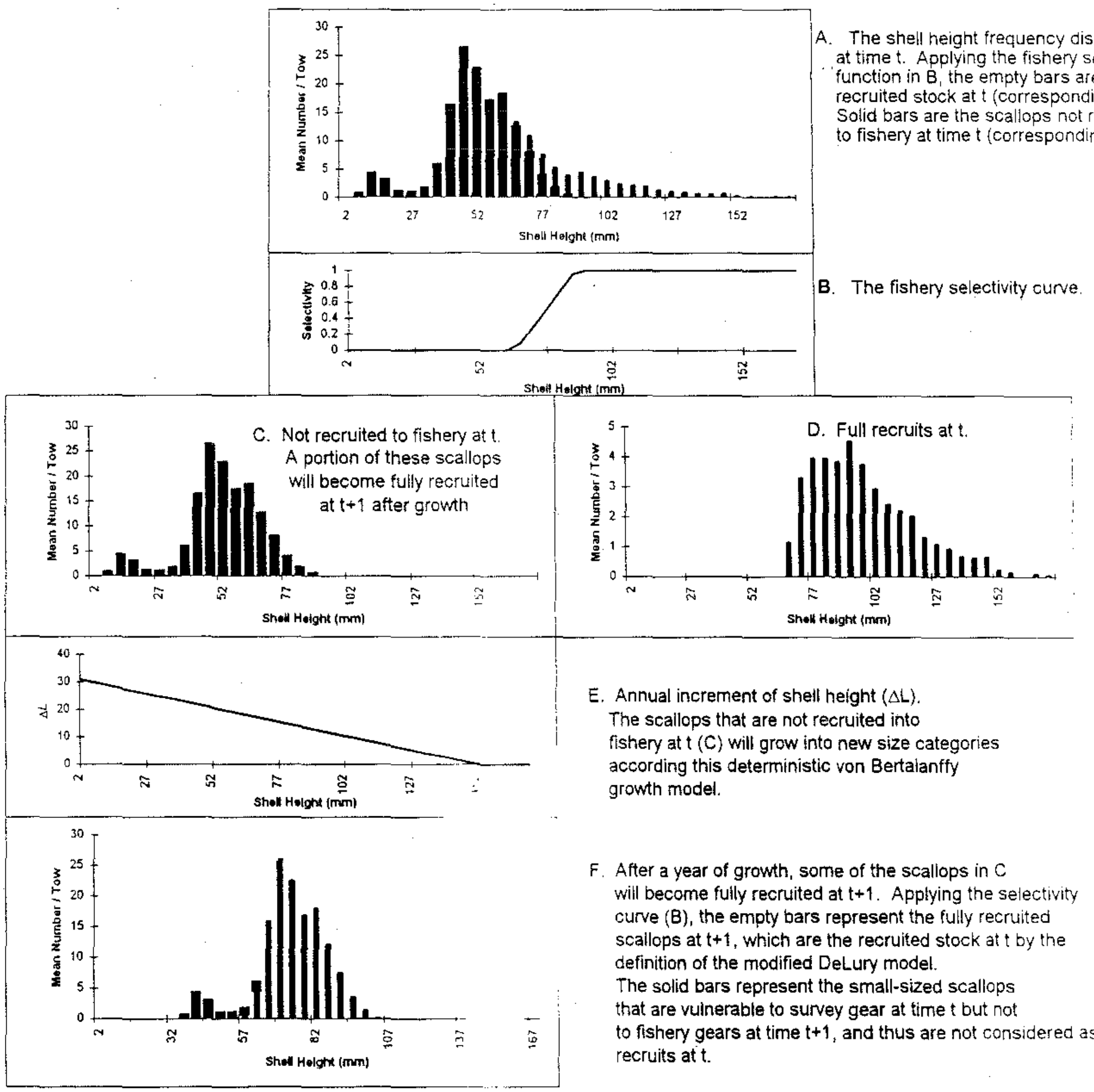


Figure B24. Schematic depiction of selectivity method used to estimate survey indices of recruited and fully-recruited stocks from the survey shell height frequency distribution.

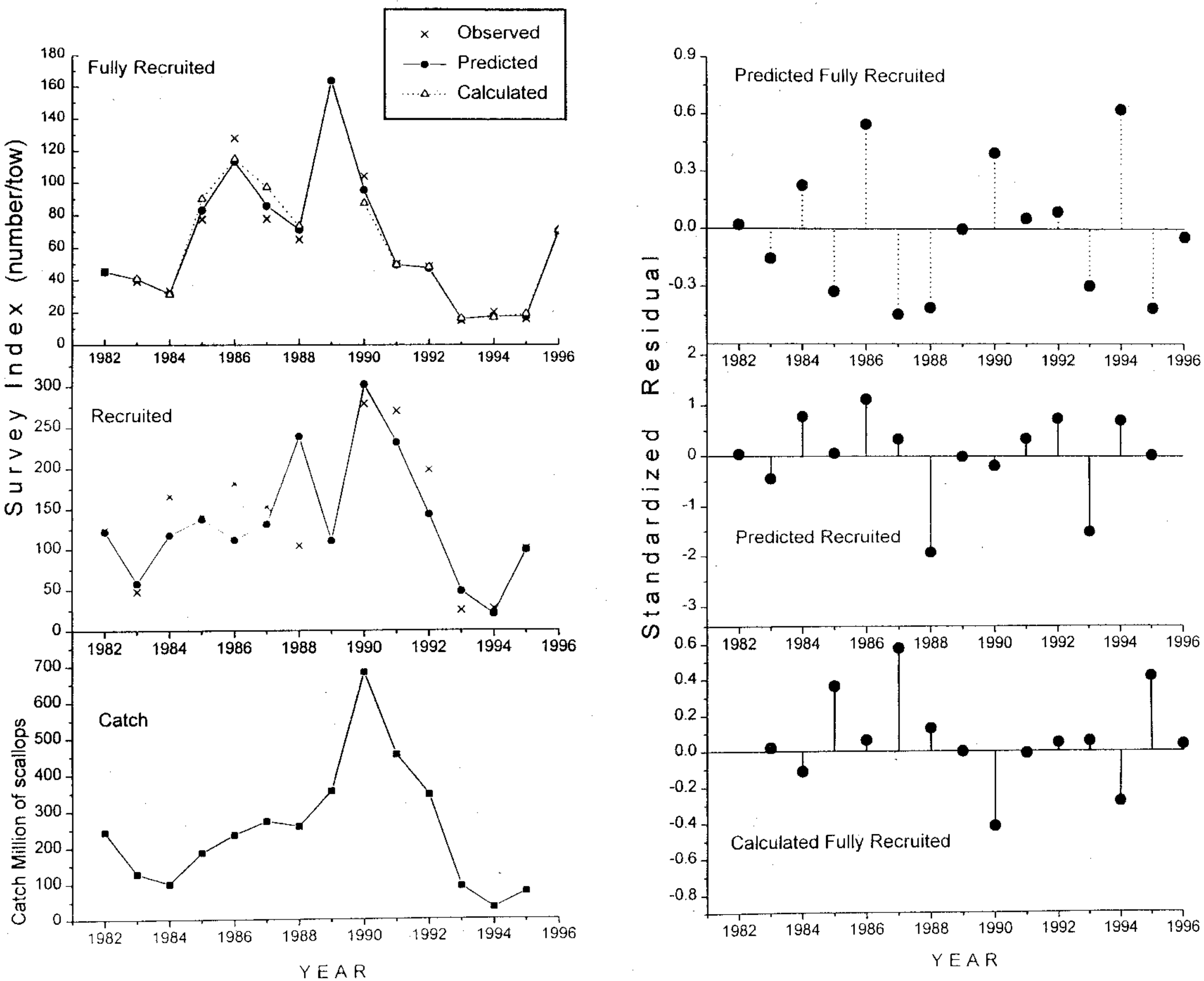


Figure B25. The results of fitting the modified DeLury model for sea scallops on Georges Bank.

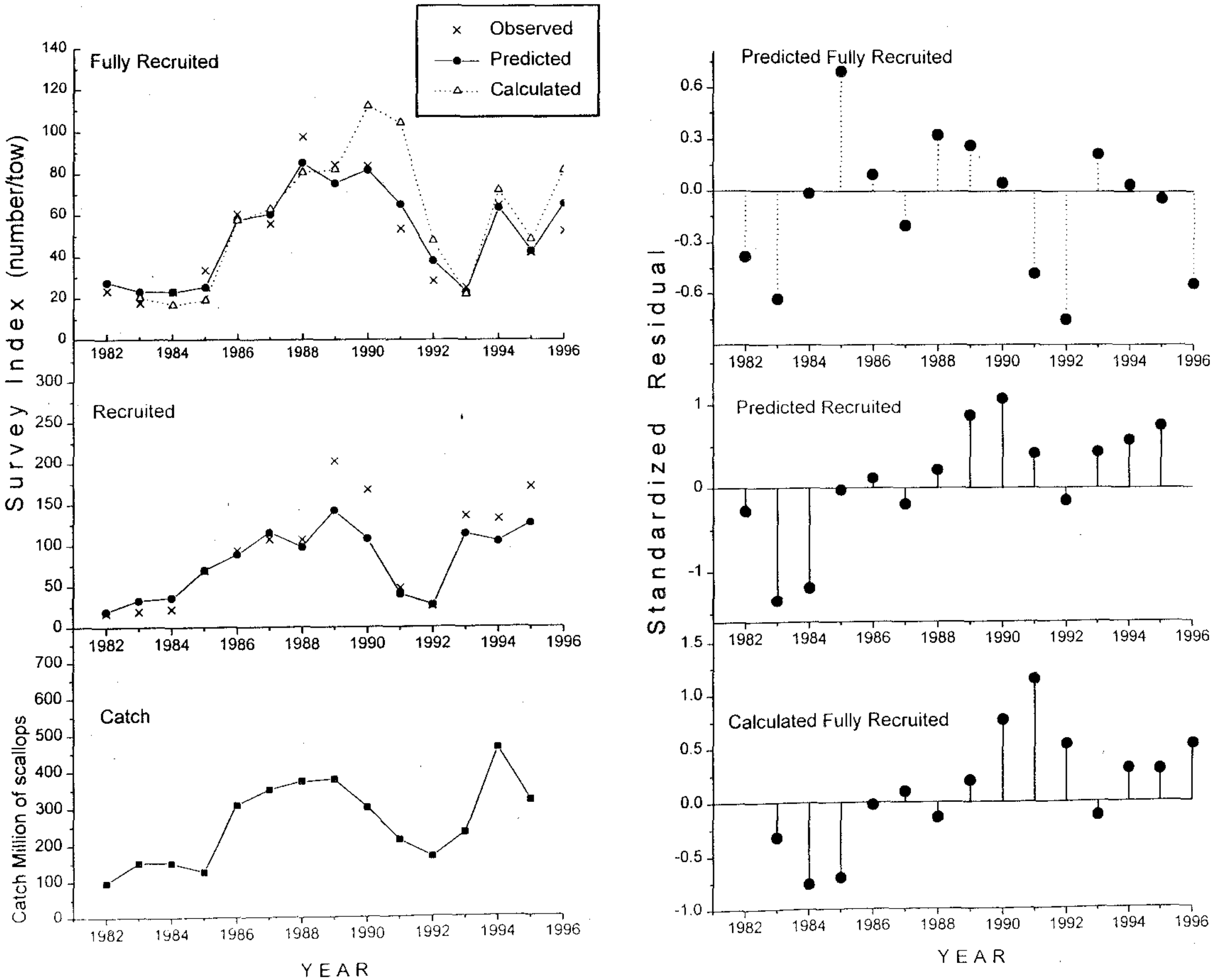


Figure B26. The results of fitting the modified DeLury model for sea scallops in the Mid-Atlantic region.

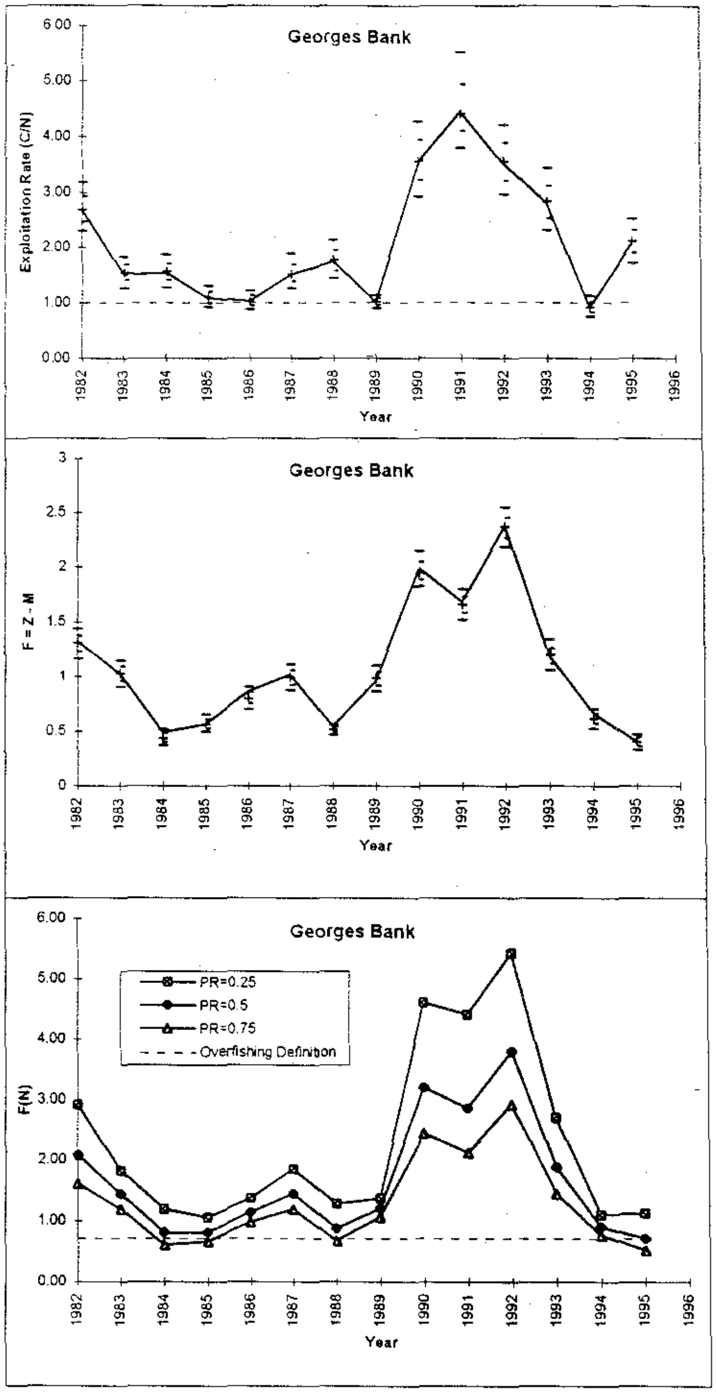


Figure B27. The estimated ratio of catch number and estimated fully-recruited stock (line) with bootstrapping percentiles (10, 25, 50, 75, and 90%), the estimated overall fishing mortality rate (line) with bootstrapping percentiles (10, 25, 50, 75, and 90%), and the estimated fishing mortality rate of fully-recruited stock estimated by applying various partial recruitment ratios, for scallops on Georges Bank.

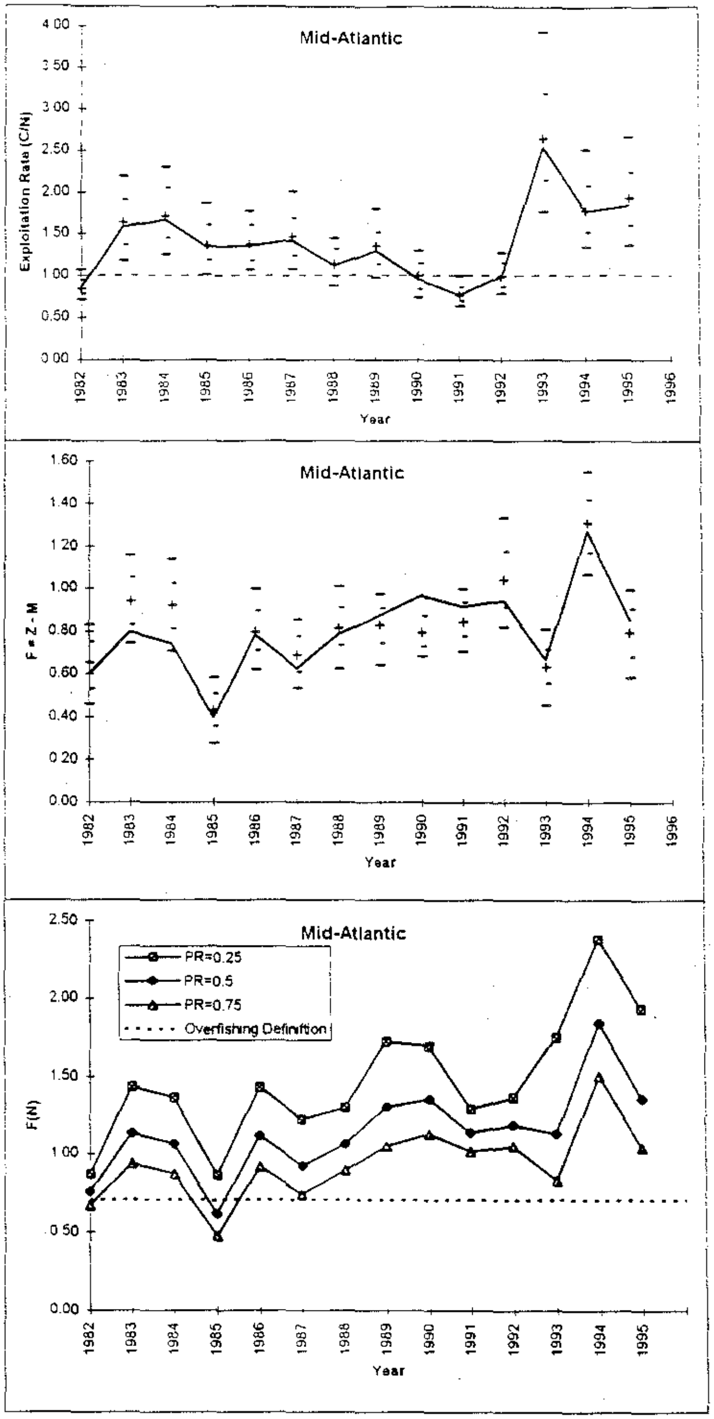


Figure B28. The estimated ratio of catch number and estimated fully-recruited stock (line) with bootstrapping percentiles (10, 25, 50, 75, and 90%), the estimated overall fishing mortality rate (line) with bootstrapping percentiles (10, 25, 50, 75, and 90%), and the estimated fishing mortality rate of fully-recruited stock estimated by applying various partial recruitment ratios, for scallops in the Mid-Atlantic region.

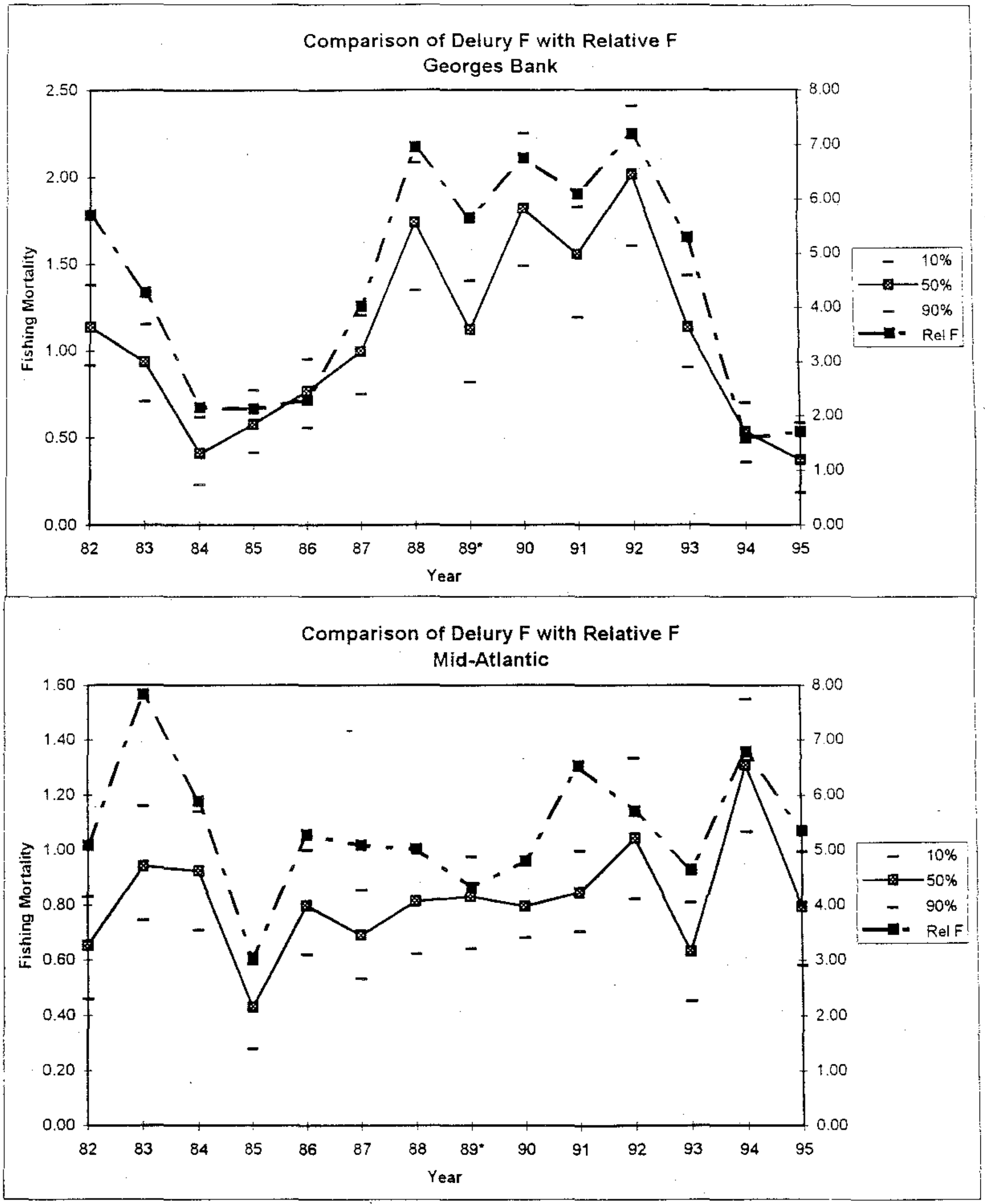


Figure B29. Comparison of relative fishing mortality estimates (right hand Y axis) with DeLury-based fishing mortality rates for Georges Bank and the Mid-Atlantic region.

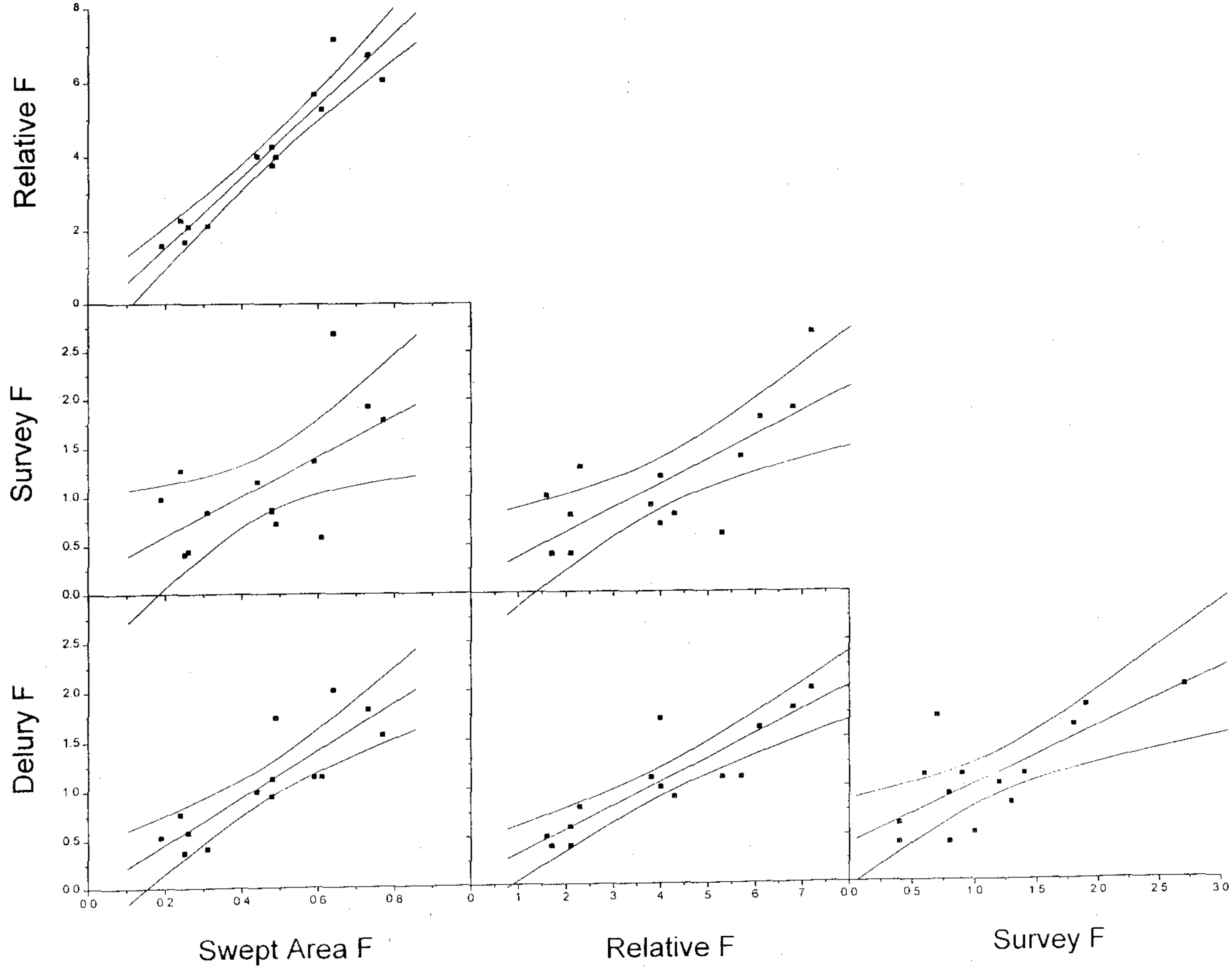


Figure B30. Comparison of estimates of fishing mortality on Georges Bank using various methods.

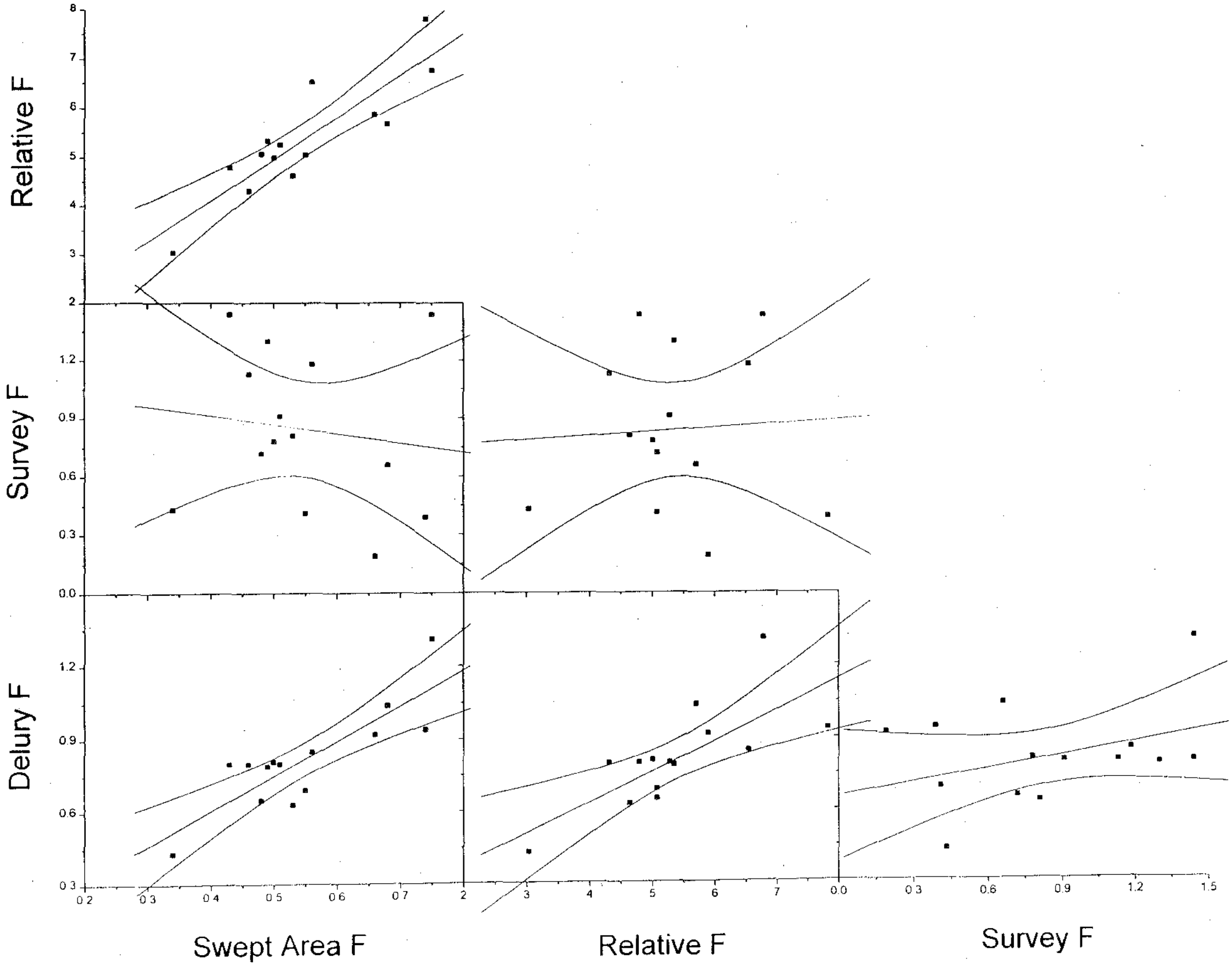


Figure B31. Comparison of estimates of fishing mortality in the Mid-Atlantic region using various methods.

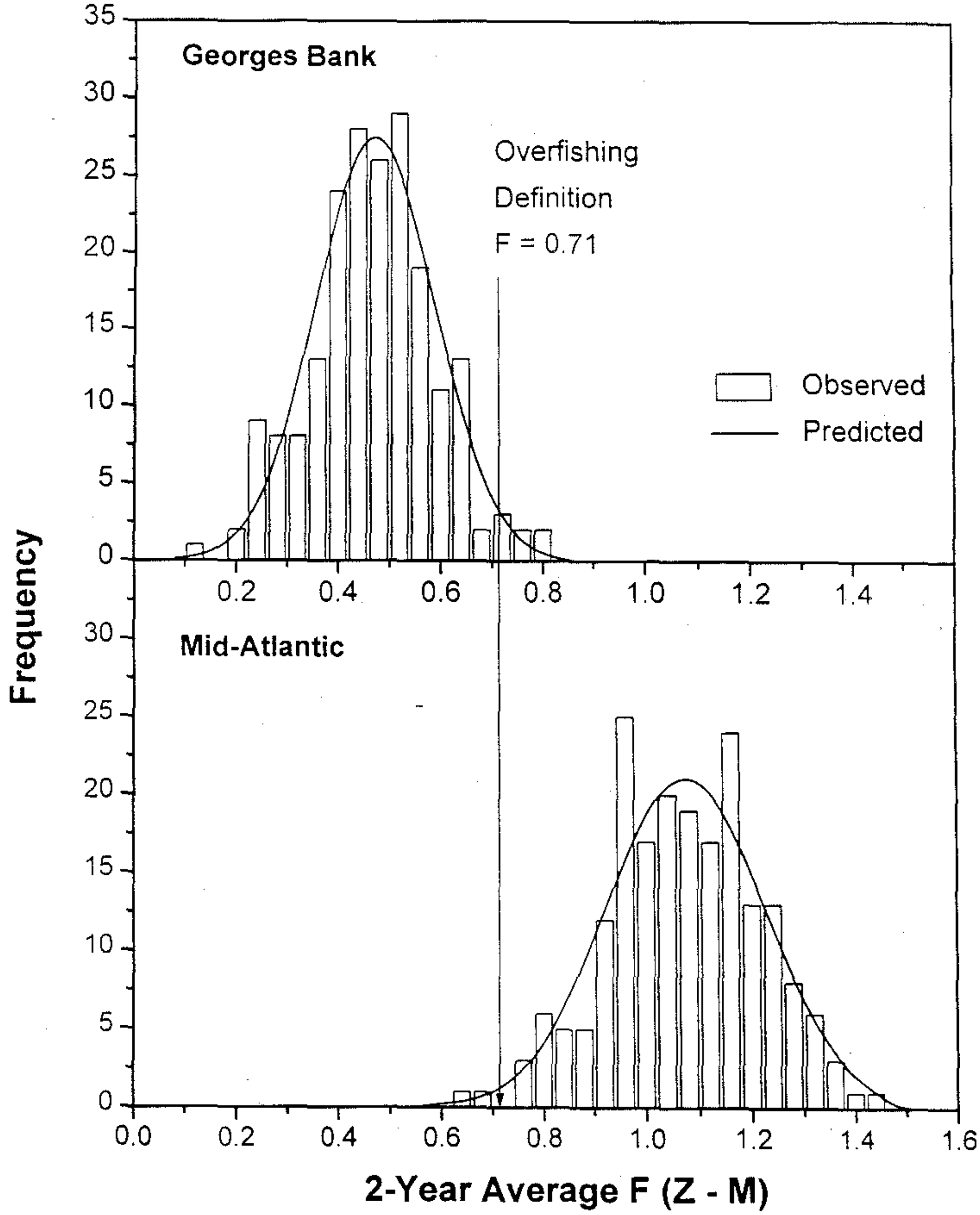


Figure B32. Frequency distributions of 200 bootstrap-estimated, 2-year average fishing mortality rates for the survey years 1994 and 1995 in the Georges Bank and Mid-Atlantic regions. The curves indicate the fitted normal distributions.

APPENDIX I

Distribution of Fishing Effort and Domestic Sea Sampling Observations for Scallop Dredge Vessels, 1992-1996

During the examination of shell height frequency distributions collected from surveys and sea samplings, a concern was raised that the geographic locations of survey stations, sea sampling tows, and fishing operation may not have the same coverage, especially when the area closure went into effect in the Georges Bank region in December 1994. To address this concern, two sources of sea sampling data were examined. The first consists of a limited number of Coast Guard overflight observations. The second data set came from the NEFSC Domestic Sea Sampling Program.

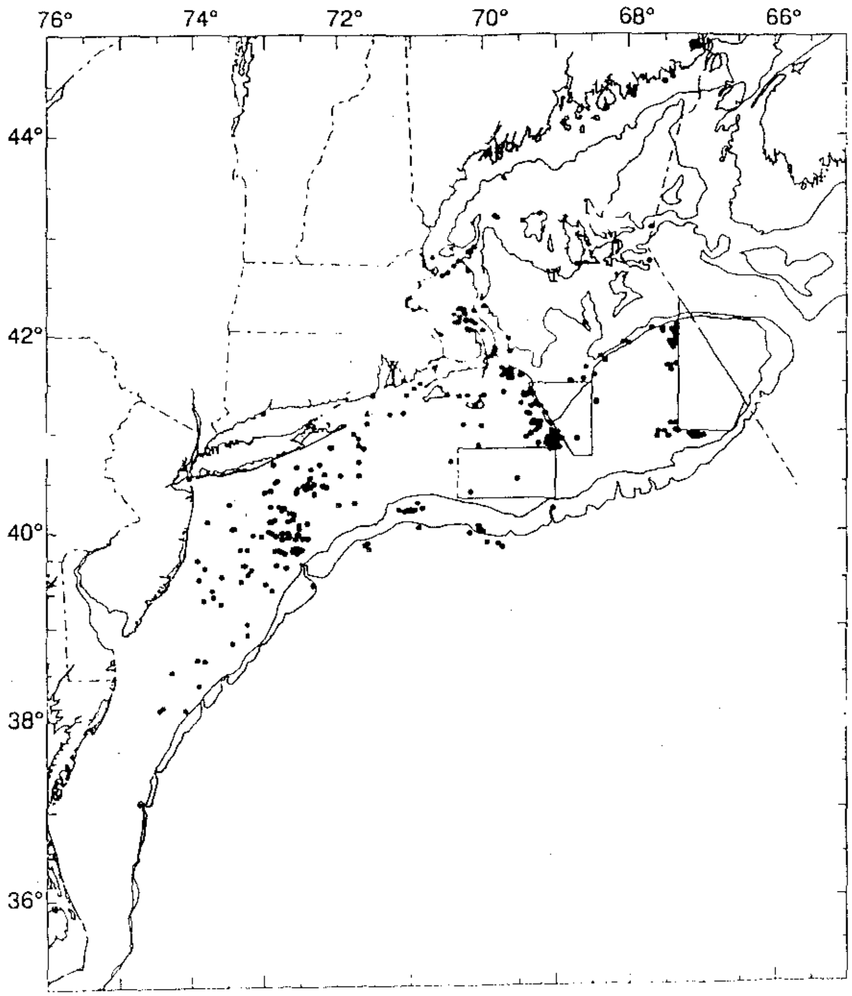
The US Coast Guard flight data collected in the periods of July-November 1995 and January-May 1996 (Appendix I Figures B1 and B2) indicated general agreement with the sea sampling locations from the NEFSC Domestic Sea Sampling Program.

The plots of locations for sea sampling tows in 1992-1996 were produced with the insertion of the three closed areas on Georges Bank (Appendix I Figures B3-B7). As shown in the SAW-20 document (NEFSC 1995), the sea sampling coverage was generally in agreement with the commercial landings based on the data aggregated into 10-minute squares from 1992 to the first half of 1994.

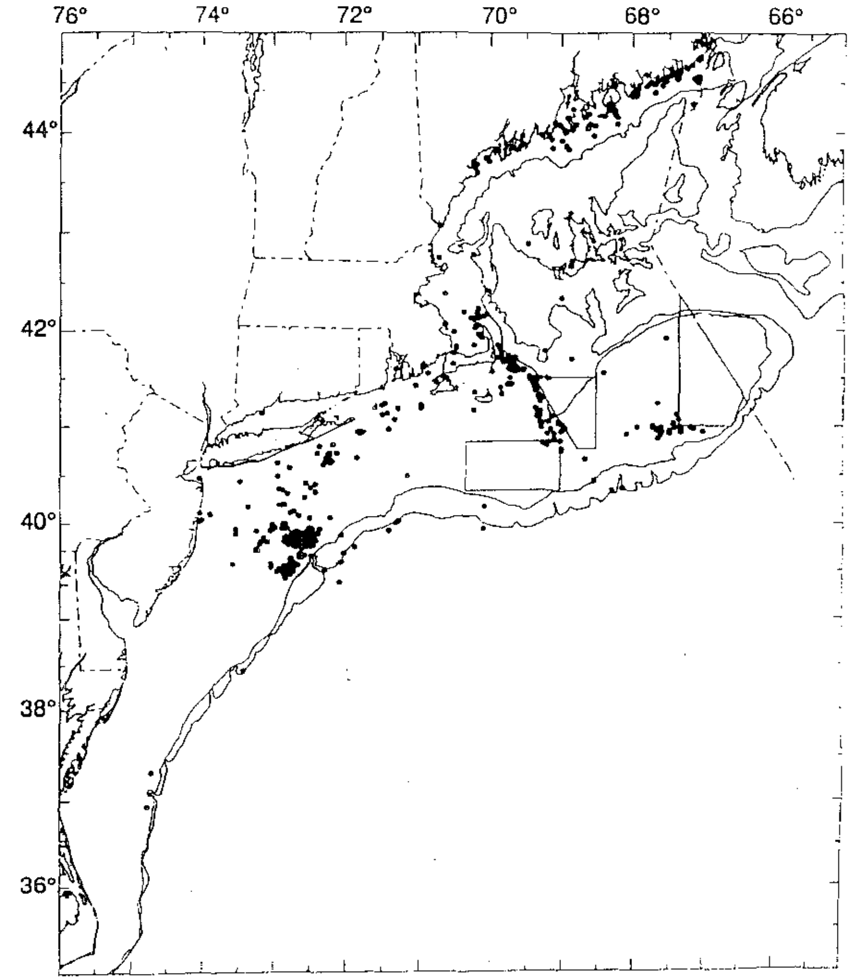
On Georges Bank, the sea sampling effort was substantially reduced in the US Northern Edge and Peak sub-region in 1994. The sea sampling locations were limited to the area adjacent to the three closed areas in 1995 and 1996.

In the Mid-Atlantic region, the area covered by sea sampling tows has expanded since 1992. This pattern indicates a shift in fishing effort from Georges Bank to the Mid-Atlantic region over the years. Since 1995, fishermen seldom harvested in the Southern New England subregion. This suggests that split trips between the George Bank and Mid-Atlantic regions are unlikely.

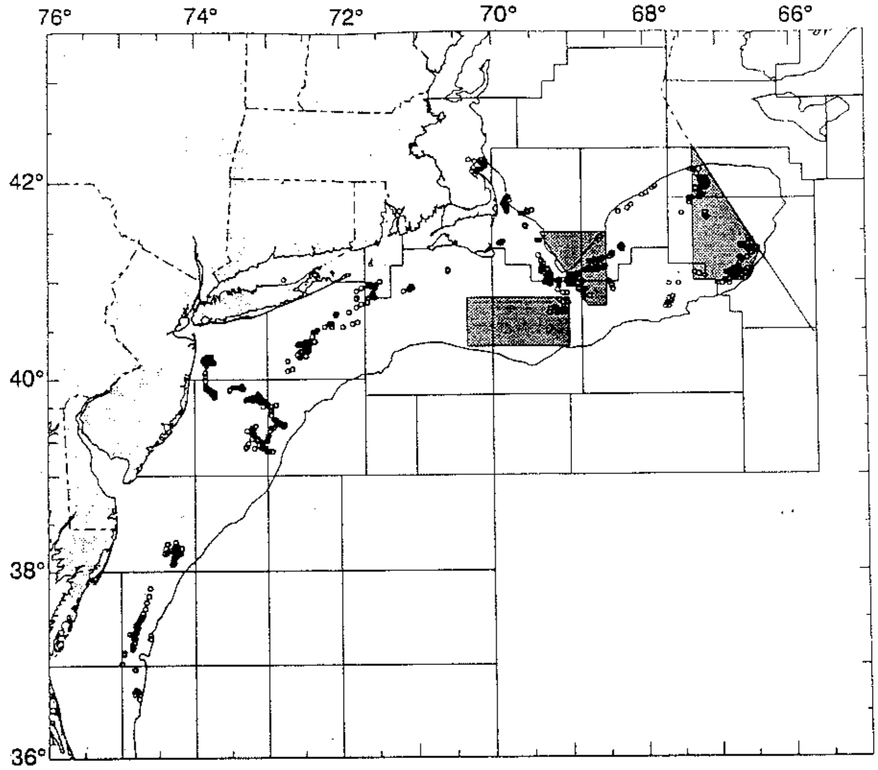
The surveys generally covered the scallop habitat in the two regions. Thus, the spatial coverage of sea sampling tows apparently did not agree with the surveys on Georges Bank. Appendix I Figures B3-B7 show the post-stratified estimates of abundance indices and shell height frequency distributions for closed and open areas in each sub-region on George Bank. With limited amount of data, the spatial aspects of growth, mortality, etc. that characterized the fisheries were not evaluated.



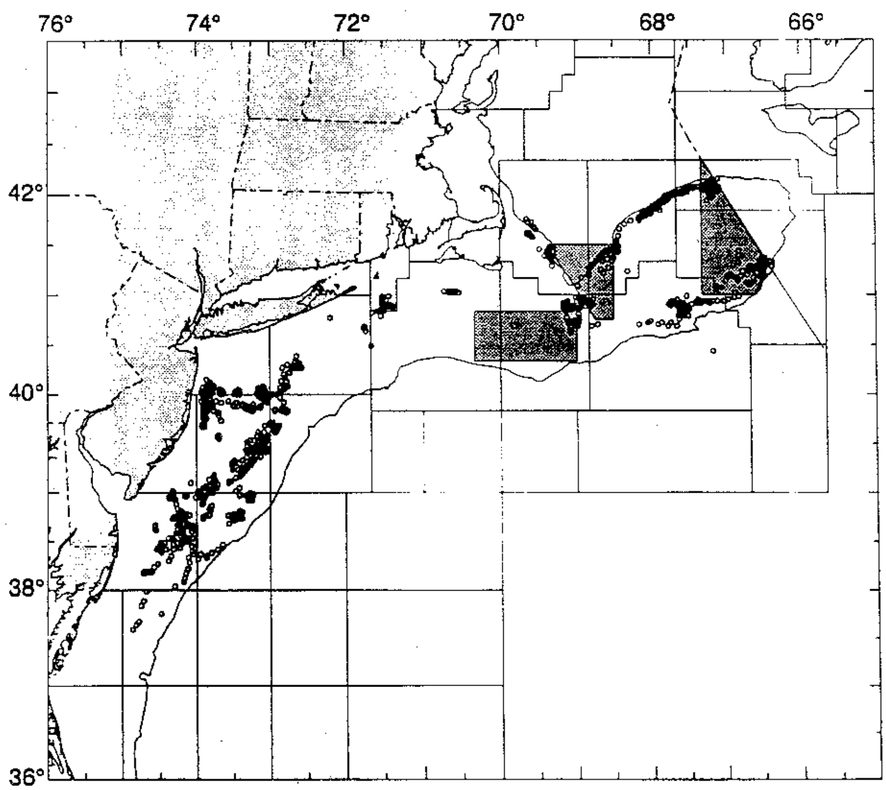
Appendix I Figure B1. Commercial sea scallop dredge vessel locations, July-November 1995.



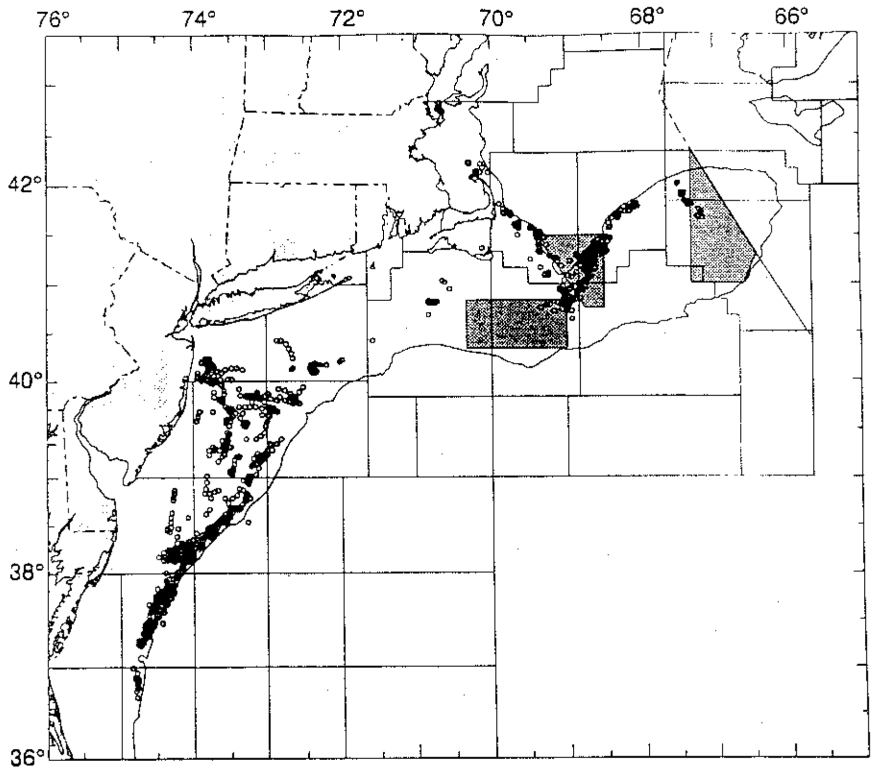
Appendix I Figure B2. Commercial sea scallop dredge vessel locations, January-May 15, 1996.



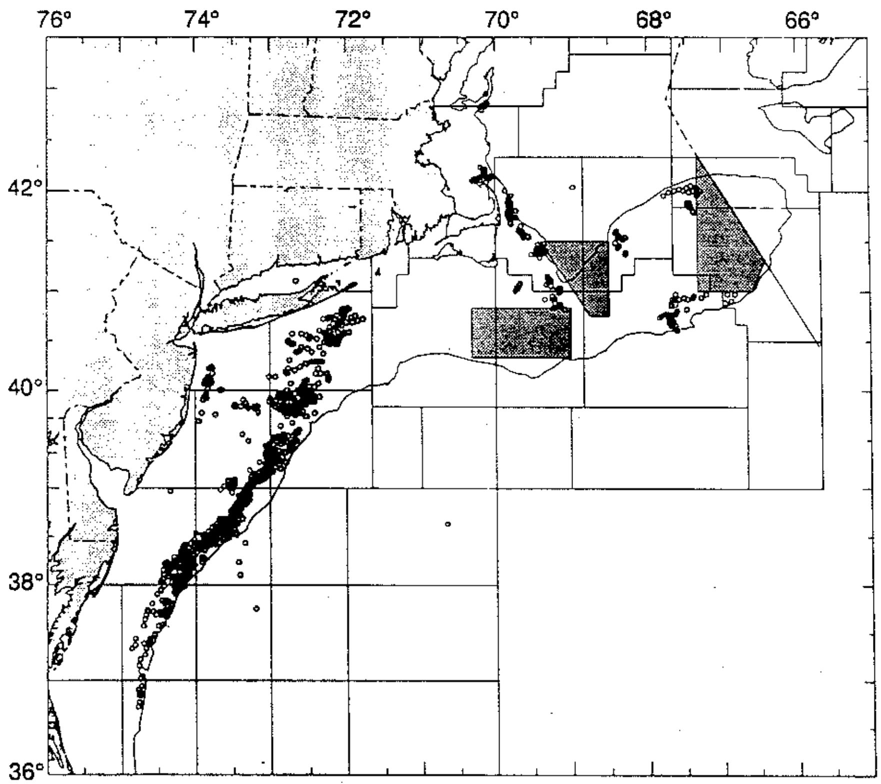
Appendix I Figure B3. Observed sea scallop tows for dredges fished during 1992, NEFSC Sea Sampling Program.



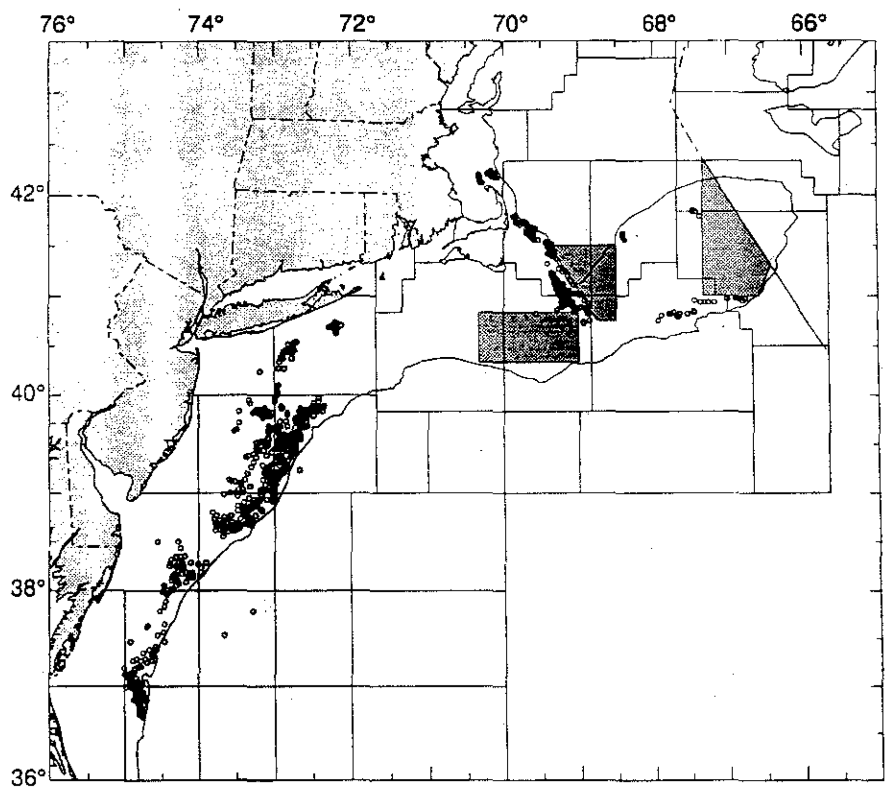
Appendix I Figure B4. Observed sea scallop tows for dredges fished during 1993, NEFSC Sea Sampling Program.



Appendix I Figure B5. Observed sea scallop tows for dredges fished during 1994, NEFSC Sea Sampling Program.



Appendix I Figure B6. Observed sea scallop tows for dredges fished during 1995, NEFSC Sea Sampling Program.

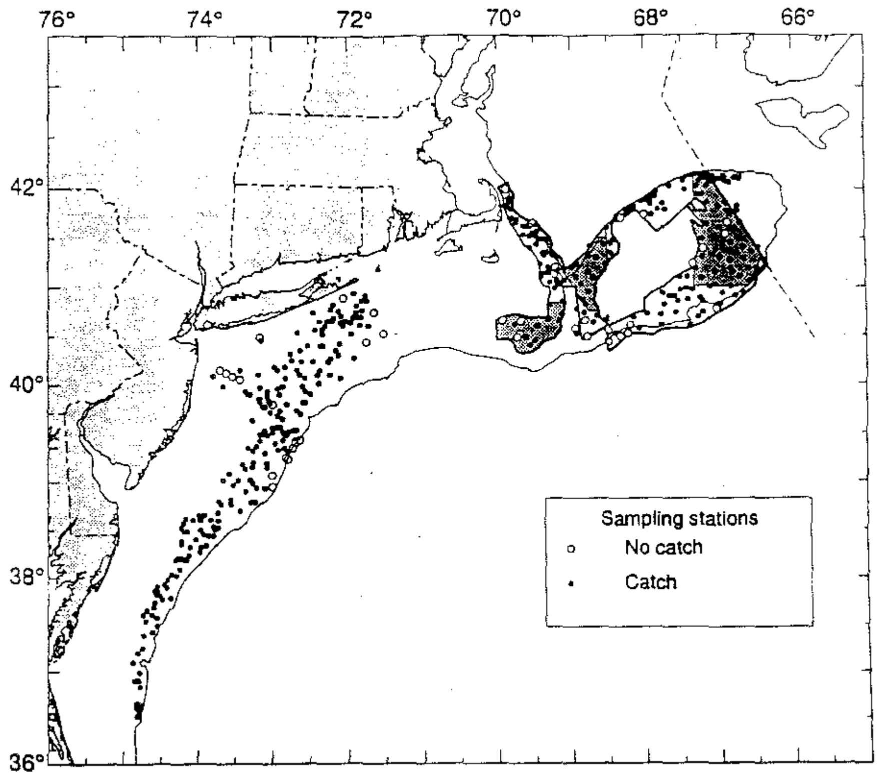


Appendix I Figure B7. Observed sea scallop tows for dredges fished during 1996, NEFSC Sea Sampling Program

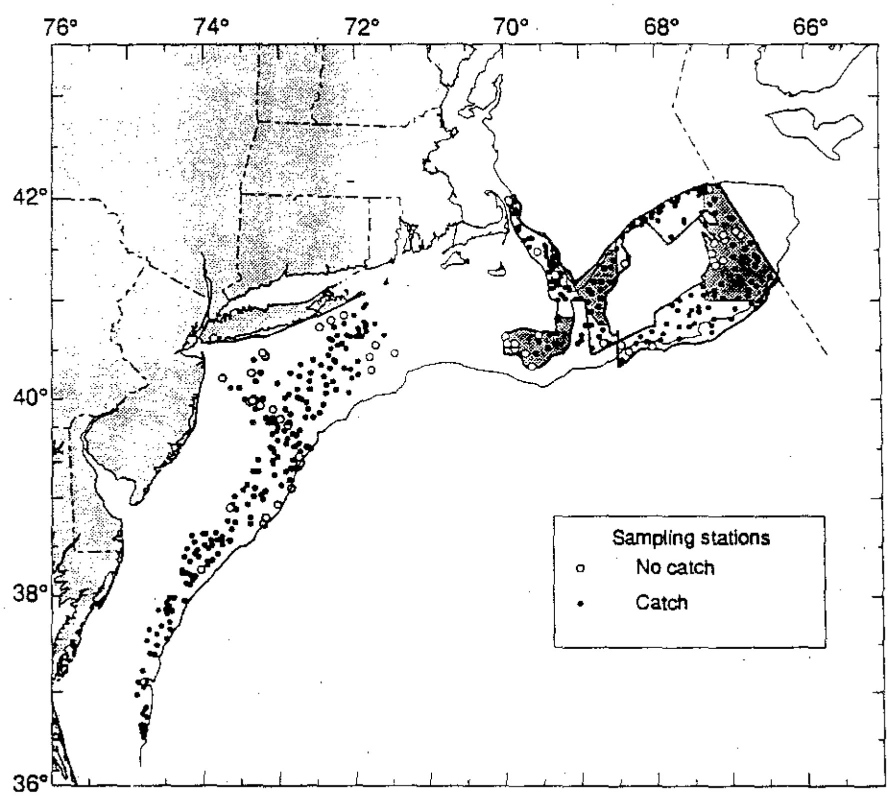
APPENDIX II

Spatial Pattern of NEFSC Sea Scallop Survey Sampling in Open and Closed Areas of Georges Bank, 1991-1996

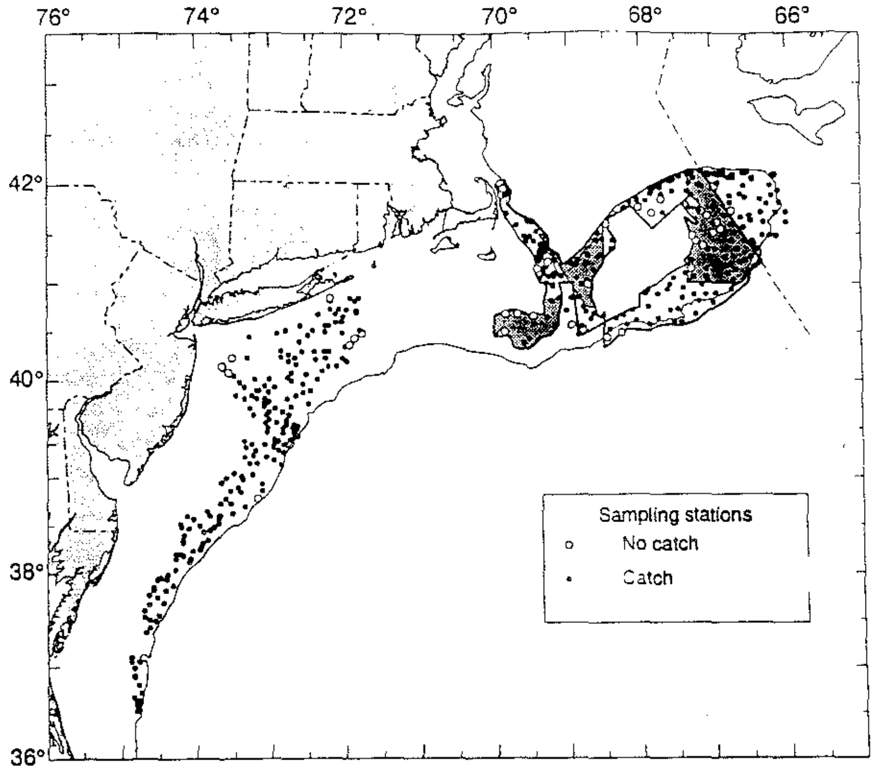
Appendix II Figures B1-B6 show the spatial pattern of sampling for the NEFSC sea scallop survey within the US EEZ. The irregular shaded areas represent the survey strata within the closed management areas. In general, the distribution of tows within and outside the closed areas appears to be evenly distributed and proportional to area.



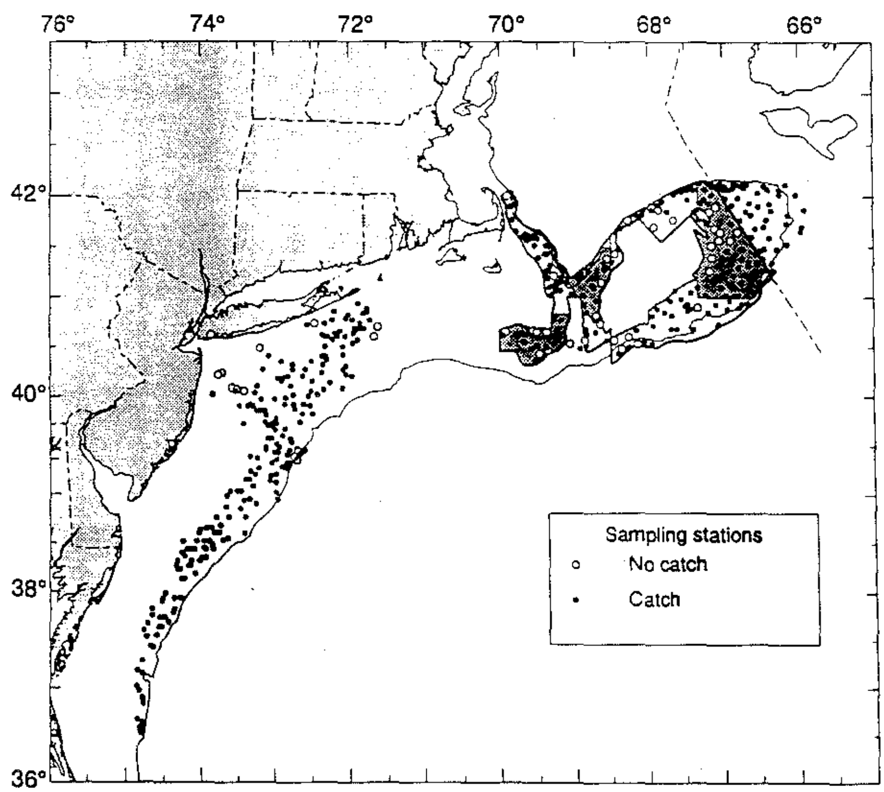
Appendix II Figure B1. NEFSC 1991 sea scallop dredge survey stations.



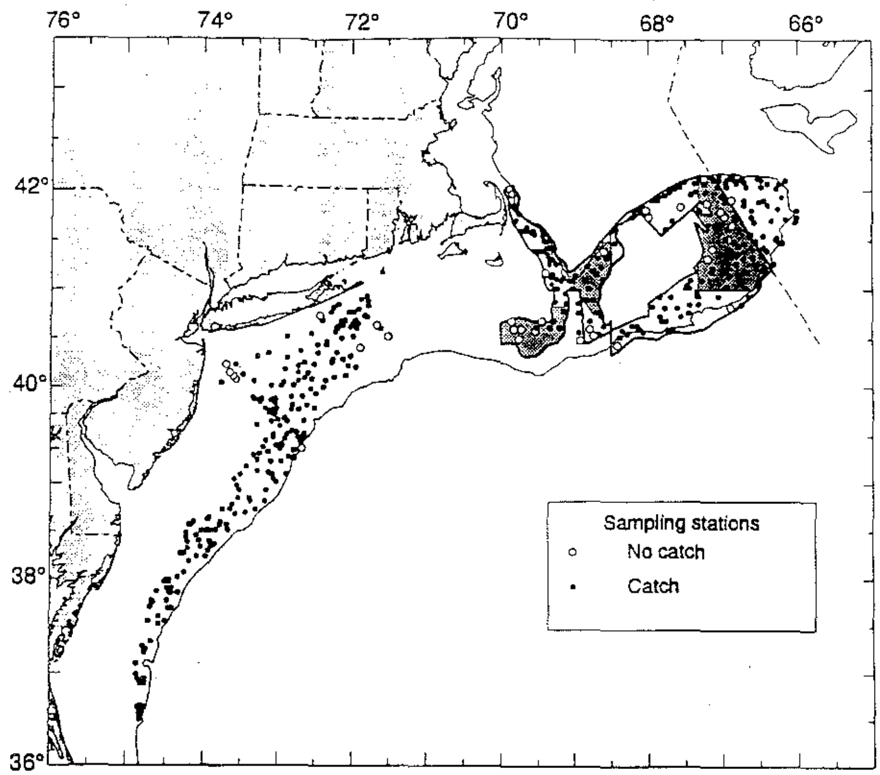
Appendix II Figure B2. NEFSC 1992 sea scallop dredge survey stations.



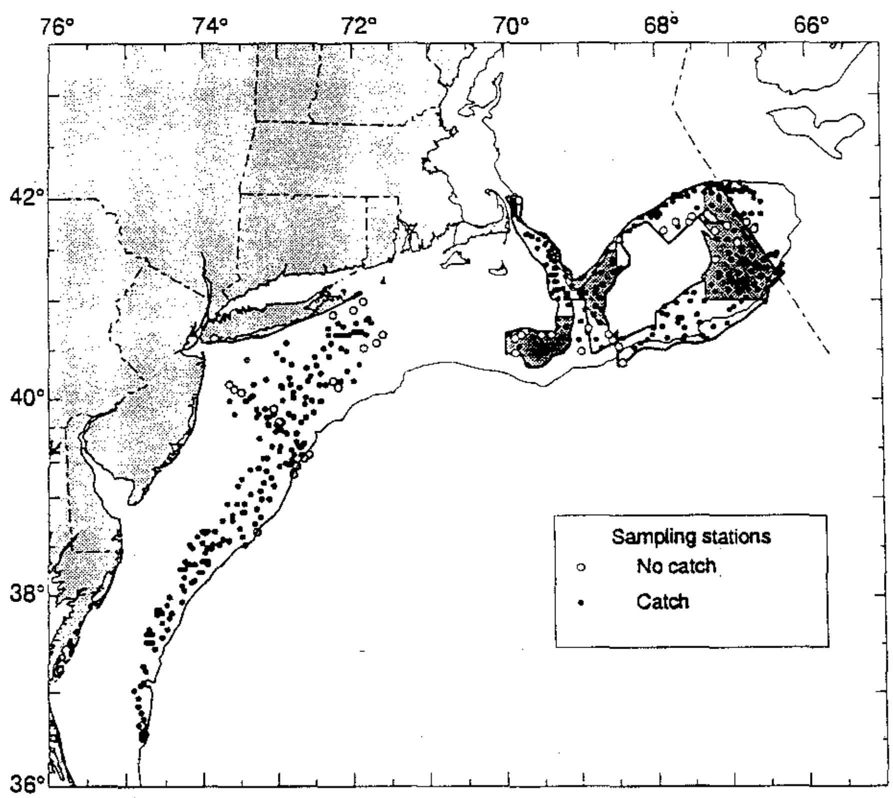
Appendix II Figure B3. NEFSC 1993 sea scallop dredge survey stations.



Appendix II Figure B4. NEFSC 1994 sea scallop dredge survey stations.



Appendix II Figure B5. NEFSC 1995 sea scallop dredge survey stations.



Appendix II Figure B6. NEFSC 1996 sea scallop dredge survey stations.

Appendix III
Detailed Summary of Delury Model application to Georges Bank.

DELURY v2.0 Oct94 Run Number 6 1996 11 17 20 50 30
Scallops: Georges Bank Sr=1.0 M=0.1 Weighting=1,1,1 1989 set to missing
Prepared for SARC 23; November 1996

Data Used

Tuning Index:	NMFS scallop dredge survey for Georges Bank strata Numbers per tow adjusted for gear selectivity
Catch data:	Derived from Weighout Database 1982-1993, Jan- Apr 1994 and VTR and Dealer Logs, 1994- June 30, 1996 Based on survey year i: July 1 yr i to Jun 30 yr i+1
Survey Years	1982-1996

Definitions

Survey Year	The period between successive NEFSC Scallop Dredge Surveys, e.g., SY1987 is 1 July 1987 to 30 June 1988.
Full-Recruits	Scallops fully vulnerable to the fishery during the entire survey yr
Recruits	Scallops that will become vulnerable to the fishery in survey yr
Size Class 2+	Full-recruits
Size Class 1	Recruits

INPUT PARAMETERS AND OPTIONS SELECTED

Input data and options read from file: R6.DAT

The survey provides indices of abundance for recruit and fully-recruited numbers at a point 50% into the calendar year. The catch is taken a at point 50% into the calendar year. Natural mortality is 0.1

CALENDAR YEAR	-- INDICES OF ABUNDANCE -- RECRUITS	FULLY-RECRUITED	TOTAL CATCH (millions)
1982	124.2870	45.6140	243.445000
1983	47.7060	39.2230	126.677000
1984	166.0260	33.5290	99.797000
1985	141.4680	77.8530	186.390000
1986	182.4260	128.1080	234.701000
1987	153.3270	78.3160	272.249000
1988	104.7480	65.5760	257.806000
1989	-999.0000	-999.0000	355.636000
1990	279.7060	104.5040	684.604000
1991	270.6420	50.3220	455.402000
1992	198.8660	48.6960	345.134000
1993	25.2780	15.1330	91.086000
1994	27.3360	20.5070	33.038000
1995	100.7870	16.1780	76.564000
1996	100.7370	70.1260	

Indices of abundance are from NEFSC Scallop Survey and are assumed to be proportional to stock abundance on July 1. Note that the recruit abundance index for the last year is NOT used in the least squares estimation. It is, however, used in conjunction with the least squares estimate of q_n and the selectivity of the recruits to calculate recruit population size in 1996 (see RESULTS section).

Estimates of biomass were not used in this assessment.

SELECTIVITY OF RECRUITS TO THE SURVEY GEAR

Selectivity of the recruits (relative to the fully-recruited animals) to the survey gear is set at 1.0 for all years.

PARTIAL RECRUITMENT (OF RECRUITS) TO THE COMMERCIAL FISHERY

A survey year (SY) is the period between successive annual surveys. Partial recruitment (PR) of the recruits to the commercial fishery is a function of month during the survey year. As animals grow in size, partial recruitment increases, eventually reaching 1.0 at the end of each survey year. The PR function may vary over SYs due to changes in regulations and/or unusually small (or large) mean size of the recruits. The annual average partial recruitment results from integrating the annual PR functions with respect to time during the SY. Annual average partial recruitment was set at 0.295 for all years.

OTHER INPUT DATA AND OPTIONS

Measurement error in the abundance indices for both the recruits and the fully-recruited is assumed to be lognormally distributed. Process error is assumed to follow a lognormal distribution.

The input objective function weights are normalized (so that they will sum to 1.0) prior to their use in the estimation. Both the original input weights and the normalized weights are given below. The square root of the normalized weights is printed in the residual tables near the end of the RESULTS section (under the heading "WEIGHT").

YEAR	-- ORIGINAL INPUT WEIGHTS -- Measurement_Error n Index	r Index	Process Error	---- NORMALIZED WEIGHTS ---- Measurement_Error n Index	r Index	Process Error
1982	4.0000	1.0000	-999.0000	0.0331	0.0083	-999.0000
1983	4.0000	1.0000	4.0000	0.0331	0.0083	0.0331
1984	4.0000	1.0000	4.0000	0.0331	0.0083	0.0331
1985	4.0000	1.0000	4.0000	0.0331	0.0083	0.0331
1986	4.0000	1.0000	4.0000	0.0331	0.0083	0.0331
1987	4.0000	1.0000	4.0000	0.0331	0.0083	0.0331
1988	4.0000	1.0000	4.0000	0.0331	0.0083	0.0331
1989	-999.0000	-999.0000	-999.0000	-999.0000	-999.0000	-999.0000
1990	4.0000	1.0000	4.0000	0.0331	0.0083	0.0331
1991	4.0000	1.0000	4.0000	0.0331	0.0083	0.0331
1992	4.0000	1.0000	4.0000	0.0331	0.0083	0.0331
1993	4.0000	1.0000	4.0000	0.0331	0.0083	0.0331
1994	4.0000	1.0000	4.0000	0.0331	0.0083	0.0331
1995	4.0000	1.0000	4.0000	0.0331	0.0083	0.0331
1996	4.0000	-999.0000	4.0000	0.0331	-999.0000	0.0331

-999 indicates that no weighting is used for that year-error type combination

Initial estimates of parameters for the Marquardt algorithm were set equal to observations. Lower and upper bounds on the parameter estimates were set to 1e-10 and 1e6, respectively. Initial estimate of Surv q_n was 1e-3 with lower and upper bounds of 1e-10 and 1e3.

RESULTS

APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

SUM OF SQUARES	0.018441
ORTHOGONALITY OFFSET.........	0.008507
MEAN SQUARE RESIDUALS	0.001537

	PARAMETER	PAR. EST.	STD. ERR.	T-STATISTIC	C.V.
1	n 2+ 1982	4.53974E1	9.69237E0	4.68383E0	0.21
2	n 2+ 1983	4.05164E1	8.23849E0	4.91794E0	0.20
3	n 2+ 1984	3.19290E1	6.64791E0	4.80285E0	0.21
4	n 2+ 1985	8.34943E1	1.64079E1	5.08867E0	0.20
5	n 2+ 1986	1.13828E2	2.12916E1	5.34616E0	0.19
6	n 2+ 1987	8.61691E1	1.67061E1	5.15793E0	0.19
7	n 2+ 1988	7.16250E1	1.47952E1	4.84111E0	0.21
8	n 2+ 1990	9.59108E1	2.00746E1	4.77773E0	0.21
9	n 2+ 1991	4.97106E1	1.06663E1	4.66053E0	0.21
10	n 2+ 1992	4.77489E1	1.01401E1	4.70891E0	0.21

11	n 2+	1993	1.61266E1	3.44289E0	4.68403E0	0.21
12	n 2+	1994	1.79047E1	3.59858E0	4.97548E0	0.20
13	n 2+	1995	1.76766E1	3.51025E0	5.03571E0	0.20
14	n 2+	1996	7.07276E1	1.43944E1	4.91355E0	0.20
15	r 1	1982	1.21945E2	2.24472E1	5.43250E0	0.18
16	r 1	1983	5.76129E1	1.38667E1	4.15476E0	0.24
17	r 1	1984	1.18074E2	2.71492E1	4.34910E0	0.23
18	r 1	1985	1.37702E2	3.56404E1	3.86365E0	0.26
19	r 1	1986	1.12060E2	3.28206E1	3.41431E0	0.29
20	r 1	1987	1.32067E2	3.13471E1	4.21304E0	0.24
21	r 1	1988	2.39704E2	4.49092E1	5.33753E0	0.19
22	r 1	1990	3.02992E2	5.41020E1	5.60037E0	0.18
23	r 1	1991	2.32513E2	3.66442E1	6.34516E0	0.16
24	r 1	1992	1.43754E2	2.70495E1	5.31450E0	0.19
25	r 1	1993	4.82884E1	8.62333E0	5.59974E0	0.18
26	r 1	1994	2.00858E1	5.88407E0	3.41359E0	0.29
27	r 1	1995	9.96394E1	2.16760E1	4.59675E0	0.22
28	Surv	q_n	5.02570E-1	6.54755E-2	7.67569E0	0.13

CORRELATION BETWEEN PARAMETERS ESTIMATED (SYMBOLIC FORM)

```
 1 n 2+ 1982 * . . . . . . . . . . . . . . . . . . . . . . . . . . .
 2 n 2+ 1983 . * . . . . . . . . . . . . + - . . . . . . . . . . . .
 3 n 2+ 1984 . . * . . . . . . . . . . . . . . . . . . . . . . . . .
 4 n 2+ 1985 . . . * . . . . . . . . . . . . + . . . . . . . . . . .
 5 n 2+ 1986 . . . . * . . . . . . . . . . . . + - . . . . . . . . .
 6 n 2+ 1987 . . . . . * . . . . . . . . . . . . + - . . . . . . . .
 7 n 2+ 1988 . . . . . . * . . . . . . . . . . . . + . . . . . . . .
 8 n 2+ 1990 . . . . . . . * . . . . . . . . . . . . + . . . . . . .
 9 n 2+ 1991 . . . . . . . . * . . . . . . . . . . . . . . . . . . .
10 n 2+ 1992 . . . . . . . . . * . . . . . . . . . . . . . . . . . .
11 n 2+ 1993 . . . . . . . . . . * . . . . . . . . . . . . . . . . .
12 n 2+ 1994 . . . . . . . . . . . * . . . . . . . . . . . . + . . .
13 n 2+ 1995 . . . . . . . . . . . . * . . . . . . . . . . . . + . .
14 n 2+ 1996 . . . . . . . . . . . . . * . . . . . . . . . . . . + .
15 r 1  1982 . + . . . . . . . . . . . . * . . . . . + + + + + . . +
16 r 1  1983 . - . . . . . . . . . . . . . * . . . . . + + + . . . +
17 r 1  1984 . . . + . . . . . . . . . . . . * . . . . . . . . . . .
18 r 1  1985 . . . . + . . . . . . . . . . . . * . . . . . . . . . .
19 r 1  1986 . . . . - + . . . . . . . . . . . . * . . . . . . . . .
20 r 1  1987 . . . . . - + . . . . . . . . . . . . * . + + + . . . +
21 r 1  1988 . . . . . . . + . . . . . . + . . . . . * . + + + . . +
22 r 1  1990 . . . . . . . . . . . . . . + + . . . + . * + + + . . *
23 r 1  1991 . . . . . . . . . . . . . . + + . . . + + + * + + . . *
24 r 1  1992 . . . . . . . . . . . . . . + + . . . + + + + * + . . *
25 r 1  1993 . . . . . . . . . . . + . . + . . . . . + + + + * . . +
26 r 1  1994 . . . . . . . . . . . . + . . . . . . . . . . . . * . .
27 r 1  1995 . . . . . . . . . . . . . + . . . . . . . . . . . . * .
28 Surv q_n  . . . . . . . . . . . . . . + + . . . + + * * * + . . *
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SYMBOLS:  =  LARGE NEGATIVE CORRELATION     whenever  -1 <= r <  -L
          -  MODERATE NEGATIVE CORRELATION  whenever  -L <= r <  -M
          .  SMALL CORRELATION              whenever  -M <= r <= +M
          +  MODERATE POSITIVE CORRELATION  whenever  +M <  r <= +L
          *  LARGE POSITIVE CORRELATION     whenever  +L <  r <= +1
```

Where r is the estimated correlation, M is 0.4 and L is 0.8

MORTALITY RATES (between surveys)

CALENDAR YEAR	STOCK SIZE ESTIMATES (millions at time of survey) RECRUITS	FULLY-RECRUITED	Z on sizes 1+	F on size 1	F on sizes 2+
1982	242.642	90.330	1.42	0.80	2.71
1983	114.637	80.619	1.12	0.52	1.74
1984	234.942	63.531	0.59	0.32	1.09
1985	273.996	166.135	0.66	0.30	1.01
1986	222.974	226.492	0.96	0.39	1.33
1987	262.783	171.457	1.11	0.52	1.77
1988	476.958	142.518	0.64	0.35	1.18
1989	221.224	327.252	1.06	0.39	1.34
1990	602.885	190.841	2.08	1.26	4.27
1991	462.649	98.913	1.78	1.18	4.00
1992	286.039	95.010	2.47	1.49	5.04
1993	96.083	32.088	1.28	0.74	2.50
1994	39.966	35.626	0.77	0.31	1.06
1995	198.260	35.172	0.51	0.30	1.01
1996	200.444	140.732			

RECRUITS = SIZECLASS 1 FULLY-RECRUITED = SIZECLASS 2+
Index of abundance for recruits is missing in 1989 For these years, the recruit stock size estimates are based on the geometric mean of recruitment in years when indices were available. Index of abundance for fully-recruited is missing in 1989 For these years, the fully-recruited stock size estimates are based on forward calculations from the DeLury difference equation. Note that the recruit population estimate for the last year (1996) is NOT a least squares estimate. It is calculated from the observed survey index, the least squares estimate of q, and the s_r.

SUMMARY OF RESIDUALS FROM THE FITTED MODEL

MEASUREMENT ERROR -- Fully-recruited index with lognormal errors

ERROR TERM	OBSERVED	PREDICTED	WEIGHT	RESIDUAL	STD RES	%SS
n 2+ 1982	45.6140	45.3974	0.1818	0.0009	0.0221	0.0
n 2+ 1983	39.2230	40.5164	0.1818	-0.0059	-0.1505	0.2
n 2+ 1984	33.5290	31.9290	0.1818	0.0089	0.2268	0.4
n 2+ 1985	77.8530	83.4943	0.1818	-0.0127	-0.3245	0.9
n 2+ 1986	128.1080	113.8281	0.1818	0.0215	0.5482	2.5
n 2+ 1987	78.3160	86.1691	0.1818	-0.0174	-0.4432	1.6
n 2+ 1988	65.5760	71.6250	0.1818	-0.0160	-0.4092	1.4
n 2+ 1989	-999.0000	164.4669	-999.0000	0.0000	0.0000	0.0
n 2+ 1990	104.5040	95.9108	0.1818	0.0156	0.3980	1.3
n 2+ 1991	50.3220	49.7106	0.1818	0.0022	0.0567	0.0
n 2+ 1992	48.6960	47.7489	0.1818	0.0036	0.0911	0.1
n 2+ 1993	15.1330	16.1266	0.1818	-0.0116	-0.2949	0.7
n 2+ 1994	20.5070	17.9047	0.1818	0.0247	0.6294	3.3
n 2+ 1995	16.1780	17.6766	0.1818	-0.0161	-0.4109	1.4
n 2+ 1996	70.1260	70.7276	0.1818	-0.0016	-0.0396	0.0
SUM				-0.0039	-0.1006	13.9

MEASUREMENT ERROR -- Recruit index with lognormal errors

ERROR TERM	OBSERVED	PREDICTED	WEIGHT	RESIDUAL	STD RES	%SS
r 1 1982	124.2870	121.9446	0.0909	0.0017	0.0441	0.0
r 1 1983	47.7060	57.6129	0.0909	-0.0172	-0.4376	1.6
r 1 1984	166.0260	118.0745	0.0909	0.0310	0.7904	5.2
r 1 1985	141.4680	137.7021	0.0909	0.0025	0.0626	0.0
r 1 1986	182.4260	112.0598	0.0909	0.0443	1.1301	10.6
r 1 1987	153.3270	132.0666	0.0909	0.0136	0.3462	1.0
r 1 1988	104.7480	239.7045	0.0909	-0.0753	-1.9198	30.7
r 1 1989	-999.0000	111.1803	-999.0000	0.0000	0.0000	0.0
r 1 1990	279.7060	302.9916	0.0909	-0.0073	-0.1854	0.3
r 1 1991	270.6420	232.5131	0.0909	0.0138	0.3521	1.0
r 1 1992	198.8660	143.7544	0.0909	0.0295	0.7526	4.7
r 1 1993	25.2780	48.2884	0.0909	-0.0588	-1.5010	18.8
r 1 1994	27.3360	20.0858	0.0909	0.0280	0.7147	4.3
r 1 1995	100.7870	99.6394	0.0909	0.0010	0.0266	0.0
SUM				0.0069	0.1755	78.3

PROCESS ERROR -- DeLury equation with lognormal errors

ERROR TERM	CALCULATED	PREDICTED	WEIGHT	RESIDUAL	STD RES	%SS
n 2+ 1983	40.7122	40.5164	0.1818	0.0009	0.0224	0.0
n 2+ 1984	31.1855	31.9290	0.1818	-0.0043	-0.1093	0.1
n 2+ 1985	90.3466	83.4943	0.1818	0.0143	0.3658	1.1
n 2+ 1986	115.3871	113.8281	0.1818	0.0025	0.0631	0.0
n 2+ 1987	97.6630	86.1691	0.1818	0.0228	0.5807	2.8
n 2+ 1988	73.6644	71.6250	0.1818	0.0051	0.1302	0.1
n 2+ 1989	-999.0000	164.4669	-999.0000	0.0000	0.0000	0.0
n 2+ 1990	87.6926	95.9108	0.1818	-0.0163	-0.4155	1.4
n 2+ 1991	49.6224	49.7106	0.1818	-0.0003	-0.0082	0.0
n 2+ 1992	48.2754	47.7489	0.1818	0.0020	0.0509	0.0
n 2+ 1993	16.3318	16.1266	0.1818	0.0023	0.0586	0.0
n 2+ 1994	16.8643	17.9047	0.1818	-0.0109	-0.2776	0.6
n 2+ 1995	19.3514	17.6766	0.1818	0.0165	0.4198	1.5
n 2+ 1996	71.3349	70.7276	0.1818	0.0016	0.0397	0.0
SUM				0.0361	0.9206	7.8

40 residual error terms
28 parameters estimated
12 degrees of freedom

Time stamp at end of run 1996 11 17 20 50 39

DELURY v2.0 Oct94 BOOTSTRAP Run Number 6 1996 11 17 21 3 56

BEGIN BOOTSTRAP REPLICATIONS

FILE HISTORY
Creation date : 1996 11 17 21 6
Last change : 1996 11 17 21 6
Last access : 1996 11 17 21 6

BOOTSTRAP TYPE : LOB
BOOTSTRAP CLASS: parametric conditional
SEED FOR THE RANDOM NUMBER GENERATOR: 74747

MAIN LOOP LIMIT IN MARQUARDT ALGORITHM: 50
NUMBER OF BOOTSTRAP REPLICATIONS ATTEMPTED: 200
NUMBER FOR WHICH NLLS CONVERGED: 200
Results from the converged replications are used for computing the statistics that follow. Other replications are ignored.

This bootstrap run finished running at timestamp: 1996 11 17 21 6 44 680

This bootstrap run was started at timestamp: 1996 11 17 21 3 56 230

BOOTSTRAP OUTPUT VARIABLE: q_hat
Catchability of the fully-recruited animals to the survey gear

PARAMETER	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
Surv q_n	5.026E-1	5.027E-1	5.220E-2	0.10

PARAMETER	MIN	PERCENTILES 10	25	MEDIAN	75	90	MAX
Surv q_n	3.500E-1	4.431E-1	4.659E-1	4.999E-1	5.394E-1	5.740E-1	6.499E-1

BOOTSTRAP OUTPUT VARIABLE: R_0
Population size (in number) of the recruits at time of the survey
i.e. 50% into the calendar year

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	2.426E2	2.452E2	1.261E1	0.05
1983	1.146E2	1.149E2	1.259E1	0.11
1984	2.349E2	2.282E2	2.854E1	0.12
1985	2.740E2	2.725E2	3.651E1	0.13
1986	2.230E2	2.096E2	3.350E1	0.15
1987	2.628E2	2.570E2	2.903E1	0.11
1988	4.770E2	4.975E2	3.414E1	0.07
1989	2.212E2	2.187E2	4.455E0	0.02
1990	6.029E2	6.033E2	2.711E1	0.04
1991	4.626E2	4.618E2	1.684E1	0.04
1992	2.860E2	2.825E2	1.194E1	0.04
1993	9.608E1	9.879E1	6.043E0	0.06
1994	3.997E1	3.837E1	7.406E0	0.19
1995	1.983E2	2.015E2	2.770E1	0.14
1996	2.004E2	2.026E2	2.140E1	0.11

YEAR	MIN	PERCENTILES 10	25	MEDIAN	75	90	MAX
1982	2.163E2	2.279E2	2.363E2	2.459E2	2.547E2	2.620E2	2.753E2
1983	8.331E1	9.917E1	1.070E2	1.146E2	1.228E2	1.310E2	1.504E2
1984	1.475E2	1.929E2	2.071E2	2.288E2	2.438E2	2.661E2	3.135E2
1985	1.695E2	2.262E2	2.461E2	2.725E2	2.996E2	3.185E2	3.675E2
1986	1.173E2	1.705E2	1.853E2	2.060E2	2.321E2	2.518E2	3.188E2
1987	1.443E2	2.205E2	2.398E2	2.570E2	2.792E2	2.907E2	3.306E2
1988	4.236E2	4.580E2	4.729E2	4.952E2	5.180E2	5.406E2	6.150E2
1989	2.082E2	2.136E2	2.156E2	2.182E2	2.222E2	2.247E2	2.307E2
1990	5.054E2	5.692E2	5.872E2	6.060E2	6.211E2	6.363E2	6.696E2
1991	4.153E2	4.409E2	4.505E2	4.623E2	4.742E2	4.827E2	5.015E2
1992	2.403E2	2.673E2	2.756E2	2.839E2	2.908E2	2.961E2	3.128E2
1993	8.297E1	9.217E1	9.494E1	9.865E1	1.028E2	1.058E2	1.184E2
1994	2.127E1	2.922E1	3.309E1	3.760E1	4.330E1	4.834E1	5.981E1
1995	1.430E2	1.690E2	1.819E2	1.973E2	2.182E2	2.426E2	2.979E2
1996	1.550E2	1.755E2	1.868E2	2.015E2	2.162E2	2.273E2	2.878E2

BOOTSTRAP OUTPUT VARIABLE: N_0
Popn size (in number) of fully-recruited animals at time of the survey
i.e. 50% into the calendar year

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	9.033E1	9.099E1	1.150E1	0.13
1983	8.062E1	8.369E1	1.229E1	0.15
1984	6.353E1	6.500E1	9.798E0	0.15
1985	1.661E2	1.717E2	2.453E1	0.15
1986	2.265E2	2.295E2	3.002E1	0.13
1987	1.715E2	1.802E2	2.801E1	0.16
1988	1.425E2	1.481E2	2.196E1	0.15
1989	3.273E2	3.509E2	3.205E1	0.10
1990	1.908E2	1.949E2	2.870E1	0.15
1991	9.891E1	1.027E2	1.608E1	0.16
1992	9.501E1	9.855E1	1.374E1	0.14
1993	3.209E1	3.252E1	4.996E0	0.16
1994	3.563E1	3.641E1	5.441E0	0.15
1995	3.517E1	3.691E1	5.683E0	0.16
1996	1.407E2	1.447E2	2.263E1	0.16

YEAR	MIN	PERCENTILES 10	25	MEDIAN	75	90	MAX
1982	6.371E1	7.655E1	8.331E1	9.062E1	9.879E1	1.058E2	1.429E2
1983	5.795E1	6.909E1	7.501E1	8.194E1	9.082E1	1.008E2	1.273E2
1984	4.379E1	5.334E1	5.825E1	6.345E1	7.050E1	7.822E1	9.722E1
1985	1.157E2	1.419E2	1.542E2	1.687E2	1.883E2	2.031E2	2.677E2
1986	1.627E2	1.930E2	2.054E2	2.296E2	2.487E2	2.691E2	3.371E2
1987	1.252E2	1.444E2	1.606E2	1.779E2	1.957E2	2.157E2	2.711E2
1988	1.070E2	1.213E2	1.328E2	1.449E2	1.635E2	1.793E2	2.407E2
1989	2.853E2	3.134E2	3.275E2	3.465E2	3.705E2	3.963E2	4.546E2
1990	1.336E2	1.603E2	1.744E2	1.923E2	2.134E2	2.344E2	2.886E2
1991	6.752E1	8.259E1	9.228E1	1.034E2	1.112E2	1.200E2	1.777E2
1992	7.017E1	8.205E1	8.882E1	9.708E1	1.074E2	1.167E2	1.424E2
1993	2.143E1	2.655E1	2.932E1	3.219E1	3.604E1	3.946E1	4.918E1
1994	2.572E1	2.922E1	3.262E1	3.565E1	3.978E1	4.367E1	5.584E1
1995	2.435E1	3.049E1	3.307E1	3.614E1	4.028E1	4.446E1	6.010E1
1996	9.823E1	1.192E2	1.286E2	1.418E2	1.554E2	1.761E2	2.198E2

BOOTSTRAP OUTPUT VARIABLE: F_N
Fishing mortality rate on the fully-recruited animals during survey yrs

SURVEY YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	2.7101	2.6832	0.2701	0.10
1983	1.7446	1.7423	0.2106	0.12
1984	1.0912	0.9742	0.1392	0.13
1985	1.0055	0.9994	0.1365	0.14
1986	1.3280	1.2095	0.1545	0.12
1987	1.7682	1.7025	0.2115	0.12
1988	1.1765	1.1235	0.0952	0.08
1989	1.3352	1.3492	0.1446	0.11
1990	4.2660	4.2156	0.4048	0.09
1991	3.9979	3.9194	0.3534	0.09
1992	5.0413	4.9893	0.4615	0.09
1993	2.5021	2.5494	0.2842	0.11
1994	1.0601	0.9648	0.1390	0.13
1995	1.0114	0.9980	0.1491	0.15

SURVEY YEAR	MIN	PERCENTILES 10	25	MEDIAN	75	90	MAX
1982	1.8181	2.3727	2.4868	2.6724	2.8633	3.0296	3.5583
1983	1.2092	1.4560	1.5952	1.7456	1.9013	2.0030	2.3663
1984	0.6157	0.8091	0.8801	0.9763	1.0610	1.1592	1.3272
1985	0.6064	0.8255	0.9044	0.9998	1.0850	1.1770	1.3598
1986	0.7541	1.0198	1.1084	1.1944	1.3204	1.4065	1.5787
1987	1.0769	1.4502	1.5504	1.6973	1.8539	1.9699	2.2144
1988	0.8581	1.0050	1.0550	1.1290	1.1912	1.2402	1.3565
1989	0.9793	1.1611	1.2389	1.3487	1.4500	1.5359	1.7487
1990	3.1012	3.7043	3.9255	4.1936	4.4927	4.7616	5.3662
1991	2.9162	3.4592	3.6902	3.9191	4.1564	4.4038	4.8141
1992	3.8145	4.4001	4.6280	4.9870	5.2714	5.6019	6.1154
1993	1.8953	2.1907	2.3417	2.5320	2.7545	2.9254	3.2766
1994	0.5399	0.8006	0.8550	0.9695	1.0438	1.1362	1.3969
1995	0.5380	0.8043	0.9012	0.9985	1.1061	1.1883	1.3615

BOOTSTRAP OUTPUT VARIABLE: F_RN
Fishing mortality rate for all animals of recruitment size and larger
i.e. recruits plus the fully-recruited group during survey years

SURVEY YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	1.3183	1.2999	0.1025	0.08
1983	1.0228	1.0262	0.0933	0.09
1984	0.4859	0.4391	0.0560	0.12
1985	0.5644	0.5649	0.0605	0.11
1986	0.8637	0.7993	0.0816	0.09
1987	1.0141	0.9910	0.0901	0.09
1988	0.5381	0.5122	0.0353	0.07
1989	0.9557	0.9814	0.0897	0.09
1990	1.9825	1.9623	0.1307	0.07
1991	1.6767	1.6544	0.1098	0.07
1992	2.3744	2.3728	0.1400	0.06
1993	1.1803	1.1927	0.1026	0.09
1994	0.6651	0.6128	0.0680	0.10
1995	0.4060	0.4032	0.0553	0.14

SURVEY YEAR	MIN	PERCENTILES 10	25	MEDIAN	75	90	MAX
1982	1.0172	1.1636	1.2278	1.3109	1.3705	1.4344	1.5663
1983	0.7744	0.9066	0.9584	1.0264	1.0937	1.1425	1.2902
1984	0.2819	0.3709	0.4010	0.4354	0.4786	0.5174	0.5710
1985	0.3875	0.4926	0.5235	0.5629	0.6129	0.6494	0.7074
1986	0.5605	0.7014	0.7505	0.7986	0.8564	0.9041	1.0031
1987	0.6971	0.8726	0.9217	0.9916	1.0553	1.1117	1.1889
1988	0.4142	0.4629	0.4884	0.5147	0.5379	0.5564	0.5975
1989	0.7526	0.8620	0.9173	0.9849	1.0406	1.1002	1.2196
1990	1.5145	1.8174	1.8805	1.9461	2.0420	2.1409	2.3206
1991	1.3615	1.5127	1.5782	1.6584	1.7281	1.7976	1.9278
1992	1.9966	2.1868	2.2680	2.3714	2.4546	2.5468	2.7454
1993	0.9200	1.0585	1.1175	1.1985	1.2586	1.3385	1.4446
1994	0.4123	0.5245	0.5680	0.6143	0.6548	0.6986	0.8255
1995	0.2397	0.3317	0.3661	0.4054	0.4442	0.4723	0.5311

BOOTSTRAP OUTPUT VARIABLE: F_RN_bar
Average fishing mortality rate for all animals of recruitment size and larger i.e. recruits plus the fully-recruited group during survey years Average fishing mortality rates on the fully-recruited animals

1st Row: F in 1995
2nd Row: Average F for 1994 1995
3rd Row: Average F for 1993 1994 1995

SURVEY YEAR(S)	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1995 0	0.4060	0.4032	0.0553	0.14
1994 95	0.5356	0.5080	0.0535	0.10
1993 95	0.7505	0.7362	0.0621	0.08

SURVEY		PERCENTILES					
YEAR(S)	MIN	10	25	MEDIAN	75	90	MAX
1995 0	0.2397	0.3317	0.3661	0.4054	0.4442	0.4723	0.5311
1994 95	0.3549	0.4344	0.4691	0.5114	0.5398	0.5809	0.6416
1993 95	0.5768	0.6531	0.6895	0.7398	0.7781	0.8155	0.8934

BOOTSTRAP OUTPUT VARIABLE: F_N_bar
Average fishing mortality rates on fully-recruited animals during survey years
1st Row: F in 1995
2nd Row: Average F for 1994 1995
3rd Row: Average F for 1993 1994 1995

SURVEY YEAR(S)	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1995 0	1.0114	0.9980	0.1491	0.15
1994 95	1.0357	0.9814	0.1233	0.12
1993 95	1.5245	1.5041	0.1654	0.11

SURVEY		PERCENTILES					
YEAR(S)	MIN	10	25	MEDIAN	75	90	MAX
1995 0	0.5380	0.8043	0.9012	0.9985	1.1061	1.1883	1.3615
1994 95	0.6586	0.8168	0.9030	0.9767	1.0636	1.1505	1.3019
1993 95	1.0708	1.2915	1.3717	1.5017	1.6214	1.7105	1.9323

Appendix IV
Detailed Summary of Delury Model application to Mid-Atlantic Region.

```
DELURY v2.0 Oct94      Run Number 102           1996 11 10 21 53 25
Scallops: Mid Atlantic Region   Sr=1.0
Prepared for SARC 23; November 1996

Data Used
-----------------------------------------------------------------------
Tuning Index:    NMFS scallop dredge survey for Mid Atlantic strata
                 Numbers per tow adjusted for gear selectivity
Catch data:      Derived from Weighout Database 1982-1993, Jan -Apr 1994
                     and VTR and Dealer Logs, 1994-June 30, 1996
                 Based on survey year i: July 1 yr i to Jun 30 yr i+1
Survey Years     1982-1996

Definitions
-----------------------------------------------------------------------
Survey Year      The period between successive NEFSC Scallop Dredge  Surveys,
                 e.g., SY1987 is 1 July 1987 to 30 June 1988.
Full-Recruits    Scallops fully vulnerable to the fishery during the entire survey yr
Recruits         Scallops that will become vulnerable to the fishery in survey yr
Size Class 2+    Full-recruits
Size Class 1     Recruits
-----------------------------------------------------------------------
```

INPUT PARAMETERS AND OPTIONS SELECTED

Input data and options read from file: R102.DAT

The survey provides indices of abundance for recruit and fully-recruited numbers at a point 0% into the calendar year. The catch is taken a at point 50% into the calendar year.

Natural mortality is 0.1

CALENDAR YEAR	-- INDICES OF ABUNDANCE -- RECRUITS	FULLY-RECRUITED	TOTAL CATCH (millions)
1982	17.2110	23.4460	97.184000
1983	19.2310	17.9720	152.041000
1984	22.0220	22.8260	151.849000
1985	68.9640	33.6550	126.465000
1986	93.2780	60.5090	310.430000
1987	107.1230	56.0200	351.326000
1988	106.5750	98.0200	372.655000
1989	203.0340	84.4720	377.877000
1990	167.6830	83.6690	301.331000
1991	48.0880	53.6910	214.049000
1992	25.8180	28.3270	167.554000
1993	136.1810	25.3470	230.408000
1994	132.4650	64.9450	464.066000
1995	171.7590	42.1460	317.505000
1996	24.4680	52.5650	

Indices of abundance are from NEFSC Scallop Survey and are assumed to be proportional to stock abundance on July 1.

Note that the recruit abundance index for the last year is NOT used in the least squares estimation. It is, however, used in conjunction with the least squares estimate of q_n and the selectivity of the recruits to calculate recruit population size in 1996 (see RESULTS section).

Estimates of biomass were not used in this assessment.

SELECTIVITY OF RECRUITS TO THE SURVEY GEAR

Selectivity of the recruits (relative to the fully-recruited animals) to the survey gear is set at: 1.0 for all years

PARTIAL RECRUITMENT (OF RECRUITS) TO THE COMMERCIAL FISHERY

A survey year (SY) is the period between successive annual surveys. Partial recruitment (PR) of the recruits to the commercial fishery is a function of month during the survey year. As animals grow in size, partial recruitment increases, eventually reaching 1.0 at the end of each survey year. The PR function may vary over SYs due to changes in regulations and/or unusually small (or large) mean size of the recruits. The annual average partial recruitment results from integrating the annual PR functions with respect to time during the SY. Annual average partial recruitment was set at 0.295 for all years.

OTHER INPUT DATA AND OPTIONS

Measurement error in the abundance indices for both the recruits and the fully-recruited is assumed to be lognormally distributed. Process error is assumed to follow a lognormal distribution.

The input objective function weights are normalized (so that they will sum to 1.0) prior to their use in the estimation. Both the original input weights and the normalized weights are given below. The square root of the normalized weights is printed in the residual tables near the end of the RESULTS section (under the heading "WEIGHT").

YEAR	-- ORIGINAL INPUT WEIGHTS -- Measurement_Error n Index	r Index	Process Error	---- NORMALIZED WEIGHTS ---- Measurement_Error n Index	r Index	Process Error
1982	1.0000	1.0000	-999.0000	0.0233	0.0233	-999.0000
1983	1.0000	1.0000	1.0000	0.0233	0.0233	0.0233
1984	1.0000	1.0000	1.0000	0.0233	0.0233	0.0233
1985	1.0000	1.0000	1.0000	0.0233	0.0233	0.0233
1986	1.0000	1.0000	1.0000	0.0233	0.0233	0.0233
1987	1.0000	1.0000	1.0000	0.0233	0.0233	0.0233
1988	1.0000	1.0000	1.0000	0.0233	0.0233	0.0233
1989	1.0000	1.0000	1.0000	0.0233	0.0233	0.0233
1990	1.0000	1.0000	1.0000	0.0233	0.0233	0.0233
1991	1.0000	1.0000	1.0000	0.0233	0.0233	0.0233
1992	1.0000	1.0000	1.0000	0.0233	0.0233	0.0233
1993	1.0000	1.0000	1.0000	0.0233	0.0233	0.0233
1994	1.0000	1.0000	1.0000	0.0233	0.0233	0.0233
1995	1.0000	1.0000	1.0000	0.0233	0.0233	0.0233
1996	1.0000	-999.0000	1.0000	0.0233	-999.0000	0.0233

-999 indicates that no weighting is used for that year-error type combination

Initial estimates of parameters for the Marquardt algorithm were set equal to observations. Lower and upper bounds on the parameter estimates were set to 1e-10 and 1e6, respectively. Initial estimate of Surv q_n was 1e-3 with lower and upper bounds of 1e-10 and 1e3.

RESULTS

APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

SUM OF SQUARES 0.049882
ORTHOGONALITY OFFSET......... 0.002784
MEAN SQUARE RESIDUALS 0.003837

	PARAMETER	PAR. EST.	STD. ERR.	T-STATISTIC	C.V.
1	n 2+ 1982	2.74053E1	9.09552E0	3.01305E0	0.33
2	n 2+ 1983	2.31693E1	7.44661E0	3.11139E0	0.32
3	n 2+ 1984	2.29479E1	7.82055E0	2.93431E0	0.34
4	n 2+ 1985	2.53611E1	9.29853E0	2.72743E0	0.37
5	n 2+ 1986	5.80467E1	1.85733E1	3.12527E0	0.32
6	n 2+ 1987	6.06765E1	2.05427E1	2.95368E0	0.34
7	n 2+ 1988	8.55670E1	2.74278E1	3.11972E0	0.32

8	n 2+	1989	7.57011E1	2.55451E1	2.96343E0	0.34
9	n 2+	1990	8.20130E1	2.65338E1	3.09088E0	0.32
10	n 2+	1991	6.53605E1	1.83394E1	3.56394E0	0.28
11	n 2+	1992	3.84003E1	1.07608E1	3.56853E0	0.28
12	n 2+	1993	2.31710E1	8.51718E0	2.72050E0	0.37
13	n 2+	1994	6.37727E1	2.08079E1	3.06483E0	0.33
14	n 2+	1995	4.28237E1	1.58713E1	2.69818E0	0.37
15	n 2+	1996	6.55607E1	2.34524E1	2.79548E0	0.36
16	r 1	1982	1.92031E1	7.15448E0	2.68407E0	0.37
17	r 1	1983	3.31578E1	1.03054E1	3.21750E0	0.31
18	r 1	1984	3.57405E1	1.10702E1	3.22854E0	0.31
19	r 1	1985	6.96000E1	2.26742E1	3.06956E0	0.33
20	r 1	1986	8.86803E1	2.87176E1	3.08801E0	0.32
21	r 1	1987	1.15578E2	3.64784E1	3.16839E0	0.32
22	r 1	1988	9.76012E1	3.37398E1	2.89276E0	0.35
23	r 1	1989	1.41920E2	4.64558E1	3.05495E0	0.33
24	r 1	1990	1.08092E2	3.74375E1	2.88727E0	0.35
25	r 1	1991	4.06004E1	1.52354E1	2.66487E0	0.38
26	r 1	1992	2.74124E1	9.95248E0	2.75433E0	0.36
27	r 1	1993	1.13872E2	3.32301E1	3.42679E0	0.29
28	r 1	1994	1.04660E2	3.08520E1	3.39233E0	0.29
29	r 1	1995	1.26243E2	3.81773E1	3.30675E0	0.30
30	Surv	q_n	2.35773E-1	3.72658E-2	6.32679E0	0.16

CORRELATION BETWEEN PARAMETERS ESTIMATED (SYMBOLIC FORM)

```
 1 n 2+ 1982 * . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 2 n 2+ 1983 . * . . . . . . . . . . . . . . - . . . . . . . . . . . . .
 3 n 2+ 1984 . . * . . . . . . . . . . . . . . - . . . . . . . . . . . .
 4 n 2+ 1985 . . . * . . . . . . . . . . . . . . . . . . . . . . . . . .
 5 n 2+ 1986 . . . . * . . . . . . . . . . . . . + . . . . . . . . . . .
 6 n 2+ 1987 . . . . . * . . . . . . . . . . . . . + . . . . . . . . . .
 7 n 2+ 1988 . . . . . . * . . . . . . . . . . . . . + . . . . . . . . .
 8 n 2+ 1989 . . . . . . . * . . . . . . . . . . . . . . . . . . . . . .
 9 n 2+ 1990 . . . . . . . . * . . . . . . . . . . . . . + . . . . . . .
10 n 2+ 1991 . . . . . . . . . * . . . . . . . . . . . . . . . . . . . .
11 n 2+ 1992 . . . . . . . . . . * . . . . . . . . . . . . . . . . . . .
12 n 2+ 1993 . . . . . . . . . . . * . . . . . . . . . . . . . . . . . .
13 n 2+ 1994 . . . . . . . . . . . . * . . . . . . . . . . . . . + - . .
14 n 2+ 1995 . . . . . . . . . . . . . * . . . . . . . . . . . . . . . .
15 n 2+ 1996 . . . . . . . . . . . . . . * . . . . . . . . . . . . . + .
16 r 1  1982 . . . . . . . . . . . . . . . * . . . . . . . . . . . . . .
17 r 1  1983 . - . . . . . . . . . . . . . . * . . . . . . . . . . . . +
18 r 1  1984 . . - . . . . . . . . . . . . . . * . . . . . . . . . . . .
19 r 1  1985 . . . . + . . . . . . . . . . . . . * . . . . . . . . . . .
20 r 1  1986 . . . . . + . . . . . . . . . . . . . * . . . . . . . . . .
21 r 1  1987 . . . . . . + . . . . . . . . . . . . . * . . . . . . . . .
22 r 1  1988 . . . . . . . . . . . . . . . . . . . . . * . . . . . . . .
23 r 1  1989 . . . . . . . . + . . . . . . . . . . . . . * . . . . . . .
24 r 1  1990 . . . . . . . . . . . . . . . . . . . . . . . * . . . . . .
25 r 1  1991 . . . . . . . . . . . . . . . . . . . . . . . . * . . . . .
26 r 1  1992 . . . . . . . . . . . . . . . . . . . . . . . . . * . . . .
27 r 1  1993 . . . . . . . . . . . . + . . . . . . . . . . . . . * . . .
28 r 1  1994 . . . . . . . . . . . . - . . . . . . . . . . . . . . * . .
29 r 1  1995 . . . . . . . . . . . . . . + . . . . . . . . . . . . . * .
30 Surv q_n  . . . . . . . . . . . . . . . . + . . . . . . . . . . . . *

SYMBOLS:  =  LARGE NEGATIVE CORRELATION     whenever  -1 <= r <  -L
          -  MODERATE NEGATIVE CORRELATION  whenever  -L <= r <  -M
          .  SMALL CORRELATION              whenever  -M <= r <= +M
          +  MODERATE POSITIVE CORRELATION  whenever  +M <  r <= +L
          *  LARGE POSITIVE CORRELATION     whenever  +L <  r <= +1
```

Where r is the estimated correlation, M is 0.4 and L is 0.8

CALENDAR YEAR	STOCK SIZE ESTIMATES (millions at time of survey) RECRUITS	FULLY-RECRUITED	MORTALITY RATES (between surveys) Z on sizes 1+	F on size 1	F on sizes 2+
1982	81.447	116.236	0.70	0.25	0.84
1983	140.634	98.270	0.90	0.40	1.36
1984	151.588	97.330	0.84	0.38	1.29
1985	295.199	107.566	0.49	0.24	0.81
1986	376.126	246.197	0.88	0.40	1.36
1987	490.208	257.351	0.72	0.34	1.16
1988	413.962	362.921	0.88	0.37	1.25
1989	601.936	321.076	0.98	0.48	1.62
1990	458.458	347.847	1.07	0.48	1.61
1991	172.201	277.218	1.02	0.37	1.25
1992	116.266	162.870	1.04	0.39	1.34
1993	482.974	98.277	0.76	0.47	1.60
1994	443.902	270.483	1.37	0.67	2.26
1995	535.442	181.631	0.95	0.53	1.79
1996	103.778	278.067			

RECRUITS = SIZECLASS 1 FULLY-RECRUITED = SIZECLASS 2+
Note that the recruit population estimate for the last year (1996) is NOT a least squares estimate. It is calculated from the observed survey index, the least squares estimate of q, and the s_r.

SUMMARY OF RESIDUALS FROM THE FITTED MODEL

MEASUREMENT ERROR -- Fully-recruited index with lognormal errors

ERROR TERM	OBSERVED	PREDICTED	WEIGHT	RESIDUAL	STD RES	%SS
n 2+ 1982	23.4460	27.4053	0.1525	-0.0238	-0.3841	1.1
n 2+ 1983	17.9720	23.1693	0.1525	-0.0387	-0.6253	3.0
n 2+ 1984	22.8260	22.9479	0.1525	-0.0008	-0.0131	0.0
n 2+ 1985	33.6550	25.3611	0.1525	0.0431	0.6966	3.7
n 2+ 1986	60.5090	58.0467	0.1525	0.0063	0.1023	0.1
n 2+ 1987	56.0200	60.6765	0.1525	-0.0122	-0.1966	0.3
n 2+ 1988	98.0200	85.5670	0.1525	0.0207	0.3345	0.9
n 2+ 1989	84.4720	75.7011	0.1525	0.0167	0.2699	0.6
n 2+ 1990	83.6690	82.0130	0.1525	0.0030	0.0492	0.0
n 2+ 1991	53.6910	65.3605	0.1525	-0.0300	-0.4842	1.8
n 2+ 1992	28.3270	38.4003	0.1525	-0.0464	-0.7490	4.3
n 2+ 1993	25.3470	23.1710	0.1525	0.0137	0.2210	0.4
n 2+ 1994	64.9450	63.7727	0.1525	0.0028	0.0448	0.0
n 2+ 1995	42.1460	42.8237	0.1525	-0.0024	-0.0393	0.0
n 2+ 1996	52.5650	65.5607	0.1525	-0.0337	-0.5439	2.3
SUM				-0.0816	-1.3173	18.5

MEASUREMENT ERROR -- Recruit index with lognormal errors

ERROR TERM	OBSERVED	PREDICTED	WEIGHT	RESIDUAL	STD RES	%SS
r 1 1982	17.2110	19.2031	0.1525	-0.0167	-0.2696	0.6
r 1 1983	19.2310	33.1578	0.1525	-0.0831	-1.3411	13.8
r 1 1984	22.0220	35.7405	0.1525	-0.0738	-1.1921	10.9
r 1 1985	68.9640	69.6000	0.1525	-0.0014	-0.0226	0.0
r 1 1986	93.2780	88.6803	0.1525	0.0077	0.1244	0.1
r 1 1987	107.1230	115.5779	0.1525	-0.0116	-0.1870	0.3
r 1 1988	106.5750	97.6012	0.1525	0.0134	0.2165	0.4
r 1 1989	203.0340	141.9203	0.1525	0.0546	0.8816	6.0
r 1 1990	167.6830	108.0920	0.1525	0.0670	1.0810	9.0
r 1 1991	48.0880	40.6004	0.1525	0.0258	0.4167	1.3
r 1 1992	25.8180	27.4124	0.1525	-0.0091	-0.1475	0.2
r 1 1993	136.1810	113.8724	0.1525	0.0273	0.4404	1.5
r 1 1994	132.4650	104.6602	0.1525	0.0359	0.5800	2.6
r 1 1995	171.7590	126.2429	0.1525	0.0470	0.7580	4.4
SUM				0.0829	1.3387	51.0

PROCESS ERROR -- DeLury equation with lognormal errors

ERROR TERM	CALCULATED	PREDICTED	WEIGHT	RESIDUAL	STD RES	%SS
n 2+ 1983	20.3772	23.1693	0.1525	-0.0196	-0.3161	0.8
n 2+ 1984	16.8680	22.9479	0.1525	-0.0469	-0.7578	4.4
n 2+ 1985	19.0476	25.3611	0.1525	-0.0437	-0.7048	3.8
n 2+ 1986	57.5615	58.0467	0.1525	-0.0013	-0.0207	0.0
n 2+ 1987	63.1426	60.6765	0.1525	0.0061	0.0981	0.1
n 2+ 1988	80.6882	85.5670	0.1525	-0.0090	-0.1445	0.2
n 2+ 1989	82.1605	75.7011	0.1525	0.0125	0.2016	0.3
n 2+ 1990	112.1639	82.0130	0.1525	0.0477	0.7708	4.6
n 2+ 1991	104.4333	65.3605	0.1525	0.0715	1.1537	10.2
n 2+ 1992	47.8717	38.4003	0.1525	0.0336	0.5427	2.3
n 2+ 1993	21.9718	23.1710	0.1525	-0.0081	-0.1308	0.1
n 2+ 1994	72.3274	63.7727	0.1525	0.0192	0.3099	0.7
n 2+ 1995	48.3263	42.8237	0.1525	0.0184	0.2976	0.7
n 2+ 1996	81.7695	65.5607	0.1525	0.0337	0.5439	2.3
SUM				0.1142	1.8435	30.5

43 residual error terms
30 parameters estimated
13 degrees of freedom

Time stamp at end of run 1996 11 10 21 53 32

DELURY v2.0 Oct94 BOOTSTRAP Run Number 102 1996 11 10 21 56 29
BEGIN BOOTSTRAP REPLICATIONS

Time stamp at end of run 1996 11 10 21 58 39
FILE HISTORY
Creation date : 1996 11 10 21 58
Last change : 1996 11 10 21 58
Last access : 1996 11 10 21 58

BOOTSTRAP RESULTS FOR RUN NUMBER 102 1996 11 10 22 4 25
Scallops: Mid Atlantic Region Sr=1.0
Prepared for SARC 23; November 1996

BOOTSTRAP TYPE : LOB
BOOTSTRAP CLASS: parametric conditional
SEED FOR THE RANDOM NUMBER GENERATOR: 74747

MAIN LOOP LIMIT IN MARQUARDT ALGORITHM: 50
NUMBER OF BOOTSTRAP REPLICATIONS ATTEMPTED: 200
NUMBER FOR WHICH NLLS CONVERGED: 200
Results from the converged replications are used for computing the statistics that follow. Other replications are ignored.

This bootstrap run finished running at timestamp: 1996 11 10 21 58 39 890
This bootstrap run was started at timestamp: 1996 11 10 21 56 29 230

BOOTSTRAP OUTPUT VARIABLE: q_hat
Catchability of the fully-recruited animals to the survey gear

PARAMETER	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
Surv q_n	2.358E-1	2.587E-1	2.238E-2	0.09

PARAMETER	MIN	10	25	MEDIAN	75	90	MAX
		PERCENTILES					
Surv q_n	1.990E-1	2.307E-1	2.413E-1	2.586E-1	2.749E-1	2.870E-1	3.156E-1

BOOTSTRAP OUTPUT VARIABLE: R_0
Population size (in number) of the recruits at time of the survey i.e. 0% into the calendar year

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	8.145E1	8.519E1	1.980E1	0.24
1983	1.406E2	1.555E2	2.602E1	0.19
1984	1.516E2	1.669E2	2.811E1	0.19
1985	2.952E2	2.928E2	5.288E1	0.18
1986	3.761E2	3.695E2	6.379E1	0.17
1987	4.902E2	4.852E2	8.074E1	0.16
1988	4.140E2	3.836E2	7.845E1	0.19
1989	6.019E2	4.900E2	9.017E1	0.15
1990	4.585E2	3.701E2	7.148E1	0.16
1991	1.722E2	1.554E2	3.788E1	0.22
1992	1.163E2	1.090E2	2.595E1	0.22
1993	4.830E2	4.495E2	7.235E1	0.15
1994	4.439E2	4.184E2	7.124E1	0.16
1995	5.354E2	4.859E2	9.369E1	0.17
1996	1.038E2	9.528E1	8.350E0	0.08

YEAR	MIN	PERCENTILES 10	25	MEDIAN	75	90	MAX
1982	3.856E1	5.978E1	6.920E1	8.470E1	9.893E1	1.097E2	1.556E2
1983	9.335E1	1.223E2	1.386E2	1.557E2	1.713E2	1.869E2	2.310E2
1984	8.345E1	1.289E2	1.481E2	1.686E2	1.857E2	1.993E2	2.503E2
1985	1.686E2	2.266E2	2.517E2	2.883E2	3.297E2	3.648E2	4.438E2
1986	2.196E2	3.008E2	3.213E2	3.579E2	4.068E2	4.570E2	5.445E2
1987	2.415E2	3.906E2	4.305E2	4.844E2	5.423E2	5.796E2	7.327E2
1988	1.950E2	2.896E2	3.214E2	3.835E2	4.355E2	4.909E2	5.954E2
1989	2.626E2	3.868E2	4.253E2	4.807E2	5.413E2	6.050E2	8.166E2
1990	2.343E2	2.818E2	3.182E2	3.654E2	4.133E2	4.625E2	6.061E2
1991	7.613E1	1.108E2	1.261E2	1.551E2	1.762E2	2.022E2	2.612E2
1992	5.847E1	7.594E1	9.116E1	1.078E2	1.262E2	1.395E2	2.690E2
1993	2.814E2	3.583E2	4.022E2	4.447E2	4.958E2	5.472E2	7.025E2
1994	2.443E2	3.242E2	3.668E2	4.158E2	4.709E2	5.114E2	6.188E2
1995	2.944E2	3.737E2	4.272E2	4.693E2	5.369E2	6.185E2	8.489E2
1996	7.754E1	8.526E1	8.899E1	9.460E1	1.014E2	1.061E2	1.230E2

BOOTSTRAP OUTPUT VARIABLE: N_0
Popn size (in number) of fully-recruited animals at time of the survey i.e. 0% into the calendar year

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	1.162E2	1.146E2	1.829E1	0.16
1983	9.827E1	9.629E1	2.210E1	0.22
1984	9.733E1	9.078E1	2.187E1	0.22
1985	1.076E2	9.491E1	2.324E1	0.22
1986	2.462E2	2.299E2	4.677E1	0.19
1987	2.574E2	2.479E2	5.967E1	0.23
1988	3.629E2	3.349E2	6.402E1	0.18
1989	3.211E2	2.920E2	6.564E1	0.20
1990	3.478E2	3.153E2	7.009E1	0.20
1991	2.772E2	2.782E2	4.754E1	0.17
1992	1.629E2	1.696E2	3.082E1	0.19
1993	9.828E1	9.119E1	2.710E1	0.28
1994	2.705E2	2.644E2	6.132E1	0.23
1995	1.816E2	1.734E2	4.752E1	0.26
1996	2.781E2	2.774E2	8.119E1	0.29

YEAR	MIN	PERCENTILES 10	25	MEDIAN	75	90	MAX
1982	6.260E1	9.091E1	1.035E2	1.152E2	1.248E2	1.356E2	1.923E2
1983	5.516E1	6.958E1	7.987E1	9.290E1	1.110E2	1.293E2	1.558E2
1984	4.563E1	6.598E1	7.417E1	8.866E1	1.048E2	1.214E2	1.585E2
1985	4.872E1	6.787E1	7.910E1	9.290E1	1.067E2	1.252E2	1.828E2
1986	1.385E2	1.753E2	1.936E2	2.261E2	2.632E2	2.899E2	3.938E2
1987	1.109E2	1.751E2	2.087E2	2.400E2	2.846E2	3.263E2	4.840E2
1988	1.958E2	2.590E2	2.843E2	3.288E2	3.775E2	4.238E2	5.737E2
1989	1.662E2	2.106E2	2.500E2	2.790E2	3.336E2	3.881E2	4.778E2
1990	1.696E2	2.340E2	2.639E2	3.033E2	3.601E2	4.105E2	5.643E2
1991	1.645E2	2.160E2	2.466E2	2.785E2	3.071E2	3.350E2	4.609E2
1992	9.418E1	1.311E2	1.451E2	1.687E2	1.917E2	2.119E2	2.575E2
1993	3.556E1	5.847E1	7.242E1	8.736E1	1.080E2	1.312E2	1.674E2
1994	1.033E2	1.858E2	2.248E2	2.621E2	3.074E2	3.473E2	4.190E2
1995	8.042E1	1.198E2	1.429E2	1.651E2	2.001E2	2.355E2	3.633E2
1996	1.359E2	1.891E2	2.178E2	2.640E2	3.262E2	3.869E2	5.737E2

BOOTSTRAP OUTPUT VARIABLE: F_R
Fishing mortality rate on the recruits during survey years

SURVEY YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	0.2492	0.2766	0.0681	0.27
1983	0.4027	0.4988	0.1000	0.25
1984	0.3823	0.5058	0.1004	0.26
1985	0.2395	0.2743	0.0788	0.33
1986	0.4027	0.4229	0.0867	0.22
1987	0.3418	0.3882	0.0756	0.22
1988	0.3705	0.3909	0.0759	0.20
1989	0.4786	0.4394	0.0777	0.16
1990	0.4768	0.3895	0.0627	0.13
1991	0.3701	0.3379	0.0531	0.14
1992	0.3945	0.4332	0.0915	0.23
1993	0.4738	0.4546	0.1090	0.23
1994	0.6669	0.6842	0.1266	0.19
1995	0.5281	0.4916	0.1079	0.20

SURVEY YEAR	MIN	PERCENTILES 10	25	MEDIAN	75	90	MAX
1982	0.1302	0.1967	0.2236	0.2746	0.3211	0.3597	0.5355
1983	0.2552	0.3755	0.4329	0.4921	0.5641	0.6407	0.7627
1984	0.2594	0.3744	0.4411	0.5001	0.5729	0.6223	0.8761
1985	0.0843	0.1706	0.2228	0.2761	0.3318	0.3761	0.4559
1986	0.1775	0.3122	0.3695	0.4223	0.4739	0.5330	0.7542
1987	0.1876	0.2849	0.3377	0.3875	0.4448	0.4823	0.5736
1988	0.1904	0.2913	0.3414	0.3929	0.4386	0.4850	0.5944
1989	0.2212	0.3476	0.3836	0.4334	0.4908	0.5495	0.6813
1990	0.2613	0.3127	0.3454	0.3845	0.4294	0.4774	0.5724
1991	0.2236	0.2738	0.3008	0.3312	0.3721	0.4095	0.5045
1992	0.2314	0.3197	0.3706	0.4251	0.4986	0.5583	0.7252
1993	0.1799	0.3198	0.3840	0.4483	0.5173	0.5844	0.8502
1994	0.3932	0.5327	0.5928	0.6765	0.7710	0.8404	1.1029
1995	0.2047	0.3599	0.4092	0.4894	0.5728	0.6298	0.8045

BOOTSTRAP OUTPUT VARIABLE: F_N
Fishing mortality rate on the fully-recruited animals during survey yrs

SURVEY YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	0.8440	0.9368	0.2308	0.27
1983	1.3637	1.6894	0.3387	0.25
1984	1.2946	1.7131	0.3400	0.26
1985	0.8112	0.9289	0.2670	0.33
1986	1.3640	1.4321	0.2935	0.22
1987	1.1576	1.3147	0.2560	0.22
1988	1.2548	1.3237	0.2571	0.20
1989	1.6207	1.4882	0.2630	0.16
1990	1.6146	1.3192	0.2123	0.13
1991	1.2535	1.1445	0.1798	0.14
1992	1.3361	1.4672	0.3100	0.23
1993	1.6045	1.5395	0.3691	0.23
1994	2.2584	2.3172	0.4288	0.19
1995	1.7884	1.6649	0.3655	0.20

SURVEY		PERCENTILES					
YEAR	MIN	10	25	MEDIAN	75	90	MAX
1982	0.4409	0.6663	0.7572	0.9298	1.0874	1.2181	1.8135
1983	0.8643	1.2715	1.4661	1.6667	1.9105	2.1698	2.5831
1984	0.8785	1.2679	1.4939	1.6935	1.9401	2.1075	2.9669
1985	0.2854	0.5777	0.7545	0.9350	1.1235	1.2738	1.5441
1986	0.6013	1.0572	1.2515	1.4302	1.6049	1.8049	2.5541
1987	0.6353	0.9649	1.1435	1.3122	1.5064	1.6333	1.9426
1988	0.6446	0.9864	1.1562	1.3305	1.4854	1.6425	2.0132
1989	0.7492	1.1772	1.2992	1.4678	1.6623	1.8610	2.3074
1990	0.8848	1.0590	1.1699	1.3022	1.4541	1.6169	1.9386
1991	0.7571	0.9273	1.0188	1.1218	1.2602	1.3868	1.7087
1992	0.7836	1.0826	1.2550	1.4395	1.6886	1.8906	2.4560
1993	0.6093	1.0831	1.3004	1.5183	1.7517	1.9793	2.8792
1994	1.3317	1.8040	2.0077	2.2909	2.6111	2.8462	3.7352
1995	0.6934	1.2189	1.3858	1.6574	1.9399	2.1329	2.7245

BOOTSTRAP OUTPUT VARIABLE: F_RN
Fishing mortality rate for all animals of recruitment size and larger
i.e. recruits plus the fully-recruited group during survey years

SURVEY YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	0.5990	0.6502	0.1421	0.24
1983	0.7979	0.9452	0.1680	0.21
1984	0.7390	0.9241	0.1669	0.23
1985	0.3922	0.4325	0.1183	0.30
1986	0.7830	0.8051	0.1498	0.19
1987	0.6226	0.6965	0.1259	0.20
1988	0.7836	0.8203	0.1437	0.18
1989	0.8759	0.8253	0.1266	0.14
1990	0.9677	0.8096	0.1041	0.11
1991	0.9150	0.8493	0.1095	0.12
1992	0.9439	1.0544	0.1999	0.21
1993	0.6650	0.6353	0.1443	0.22
1994	1.2694	1.3026	0.1931	0.15
1995	0.8473	0.7954	0.1607	0.19

SURVEY YEAR	MIN	PERCENTILES 10	25	MEDIAN	75	90	MAX
1982	0.3183	0.4578	0.5303	0.6528	0.7491	0.8295	1.0166
1983	0.4999	0.7435	0.8302	0.9405	1.0513	1.1576	1.4003
1984	0.5345	0.7072	0.8134	0.9234	1.0235	1.1380	1.3825
1985	0.1206	0.2786	0.3577	0.4291	0.5084	0.5850	0.7303
1986	0.2996	0.6200	0.7109	0.7979	0.8967	0.9979	1.3155
1987	0.3884	0.5324	0.6071	0.6903	0.7762	0.8537	1.0129
1988	0.4734	0.6218	0.7339	0.8144	0.9106	1.0092	1.2279
1989	0.4280	0.6416	0.7437	0.8306	0.9090	0.9734	1.1737
1990	0.5989	0.6799	0.7306	0.7952	0.8742	0.9617	1.1263
1991	0.6027	0.7048	0.7754	0.8457	0.9362	0.9963	1.1668
1992	0.6106	0.8207	0.9153	1.0432	1.1749	1.3321	1.7033
1993	0.2550	0.4528	0.5533	0.6315	0.7135	0.8099	1.1896
1994	0.7553	1.0667	1.1700	1.3094	1.4158	1.5489	1.8791
1995	0.4081	0.5813	0.6777	0.7943	0.9006	0.9911	1.2015

BOOTSTRAP OUTPUT VARIABLE: F_RN_bar
Average fishing mortality rate for all animals of recruitment size and larger i.e. recruits plus the fully-recruited group during survey years Average fishing mortality rates on the fully-recruited animals
1st Row: F in 1995
2nd Row: Average F for 1994 1995
3rd Row: Average F for 1993 1994 1995

SURVEY YEAR(S)	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1995 0	0.8473	0.7954	0.1607	0.19
1994 95	1.0584	1.0490	0.1458	0.14
1993 95	0.9272	0.9111	0.1189	0.13

SURVEY YEAR(S)	MIN	PERCENTILES 10	25	MEDIAN	75	90	MAX
1995 0	0.4081	0.5813	0.6777	0.7943	0.9006	0.9911	1.2015
1994 95	0.6031	0.8779	0.9488	1.0452	1.1481	1.2355	1.4034
1993 95	0.5185	0.7745	0.8252	0.9038	1.0014	1.0637	1.2151

BOOTSTRAP OUTPUT VARIABLE: F_N_bar
Average fishing mortality rates on fully-recruited animals during survey years
1st Row: F in 1995
2nd Row: Average F for 1994 1995
3rd Row: Average F for 1993 1994 1995

SURVEY YEAR(S)	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1995 0	1.7884	1.6649	0.3655	0.20
1994 95	2.0234	1.9911	0.3477	0.17
1993 95	1.8838	1.8405	0.3155	0.17

SURVEY YEAR(S)	MIN	PERCENTILES 10	25	MEDIAN	75	90	MAX
1995 0	0.6934	1.2189	1.3858	1.6574	1.9399	2.1329	2.7245
1994 95	1.0193	1.5457	1.7491	1.9529	2.2148	2.4578	2.9173
1993 95	0.9676	1.4760	1.5952	1.8159	2.0671	2.2392	2.8342

C. BLUEFISH

Terms of Reference

The following terms of reference were addressed for bluefish:

a. Assess the status of bluefish through 1995 and characterize the variability of estimates of stock abundance and fishing mortality rates.

b. To the extent feasible, project 1996 catches and associated fishing mortality rates and spawning biomasses.

c. To the extent feasible, provide catch projections associated with various biological reference points for 1997.

d. Identify possible causes for the decline in bluefish abundance.

Introduction

Bluefish (*Pomatomus saltatrix*) are found along the US Atlantic coast from Maine to Florida, migrating northward from the South Atlantic Bight in the spring and returning southward in the late fall. They are the target of a major recreational fishery along the Atlantic coast, with catches averaging 33,700 metric tons (mt) per year during 1979-1995. For the same period, the commercial landings of bluefish, mainly by trawls and gillnets, averaged 5,900 mt per year. The management unit for the Fishery Management Plan (FMP) for the Bluefish Fishery, developed jointly by the Mid-Atlantic Fishery Management Council (MAFMC) and the Atlantic States Marine Fisheries Commission (ASMFC), has been defined as the entire bluefish population along the Atlantic coast of the United States (MAFMC 1990).

Atlantic coast bluefish exhibit fast growth during the first two years of life, attaining fork lengths of over 40 cm by age 2 (Hamer 1959, Lassiter 1962, Richards 1976, Wilk 1977). They may reach ages of at least 12 years and sizes in excess of 100 cm fork length and 14 kg in weight. About 50% reach sexual maturity by the second year of life, and they are fully mature by age 2 (Wilk 1977). Spawning occurs during two major periods: March and April in the South Atlantic Bight near the inner edge of the Gulf Stream, with a peak about April 1, and June-September in the Mid-Atlantic Bight, with a peak about August 1 (Wilk 1977, Kendall and Walford 1979, Nyman and Conover 1988). Some spawning also occurs in the South Atlantic Bight during autumn and into early winter (September-January; McBride *et al.* 1993).

Lund and Maltezos (1970) used analysis of mark and recapture data to conclude that several bluefish populations are present along the Atlantic coast. Wilk (1977) suggested that two populations of bluefish, corresponding to the major spawning groups, exist along the Atlantic coast. Chiarella and Conover (1990) presented evidence that fish from the major spawning groups mix extensively during their lifespan, as summer spawning fish were observed to originate from both spring- and summer-spawned cohorts, and concluded that year classes of bluefish, therefore, consist of varying proportions of seasonal cohorts. Graves *et al.* (1992) used analysis of mitochondrial DNA to investigate the genetic basis of stock structure of bluefish along the Atlantic coast, and were unable to detect significant genetic differences among spring- and summer-spawned bluefish. Graves *et al.* (1992) concluded that bluefish along the Mid-Atlantic coast comprise a single genetic stock.

Fishery Data

Commercial Landings

Total US commercial landings of bluefish from Maine to Florida peaked in 1981 at nearly 7,500 mt (16.5 million lbs, Table C1). The landings in 1995 of about 3,400 mt (7.5 million lbs) represented a 22% decrease from 1994. Large variability in bluefish landings exists among the states, over time, but generally the states of North Carolina, Virginia, New Jersey, New York, Florida, Rhode Island, and Massachusetts have accounted for over 90% of the commercial landings (Table C2). In the Northeast Region (NER;

Maine-Virginia), otter trawl and gillnet landings comprised about 82% of the regional total, averaging 33% and 49%, respectively, during 1991-1993. Pound nets, purse and beach seines, and handlines accounted for the remainder (Table C3). In North Carolina, winter trawl and gillnet fisheries comprise about 78% of the commercial landings. Pound net, seine, and handline fisheries, which land fish mainly during the summer months, account for the other 22% of the landings (Table C4). In Florida, most commercial landings of bluefish are taken in the winter gillnet fishery.

Northeast Region commercial fishery

The length and age frequency sampling of bluefish landings in the Northeast Region commercial fishery during 1982-1993 was evaluated. To compare the intensity of length sampling of the commercial fishery to that of the recreational fishery, sampling intensity was expressed as metric tons of total NER landings per 100 fish lengths measured. Sampling is proportionally stratified by market category and fishing gear, with the sampling distribution generally reflecting the distribution of landings by market category and gear. Sampling intensity has been low during the entire period, has deteriorated since 1988, and was very poor during 1990-1993 (Table C5).

The length composition of the NER commercial landings for 1982-1993 was estimated annually for pooled market categories and statistical areas using standard NEFSC procedures (length frequency samples converted to mean weights by length-weight relationships; mean weights in turn divided into landings to calculate numbers at length). Length compositions were estimated by gear type when samples were adequate (1983-1988). For 1990-1993, the NER commercial fishery length sampling was judged to be inadequate to characterize the landings. To overcome this deficiency, the North Carolina (NC) commercial winter fishery proportions at length from 1990-1993 were applied to the NER commercial fishery landings to estimate landings at length.

No age data from NER fisheries were available for conversion of NER landings at length, although the age structures (scales) are archived. In the SAW-18 assessment (NEFSC 1994b), the mean weights in the NER fishery were compared with those from the NC winter fisheries (gillnet and otter trawl) as a way of judging the applicability of North Carolina Division of Marine Fisheries (NC DMF) commercial winter fishery age-length keys for ageing NER commercial fishery lengths. Since the mean weights in the fisheries were judged to be very similar, the NC DMF commercial winter fishery annual age-length keys were used to convert NER commercial fishery length data to age for 1982-1989. As noted above, since the NER commercial fishery length frequency sampling was judged inadequate for 1990-1993, the NER commercial fishery landings were assumed to have similar length and age proportions as the NC commercial winter fishery landings. Since NER commercial samples were not available for 1994 for evaluation, NER commercial fishery landings were again assumed to have the same length and age proportions as the NC commercial winter fishery landings (Tables C6-C7).

For 1995, since neither NER commercial nor NC commercial samples were available, NER commercial fishery landings were assumed to have the same length and age proportions as the 1995 recreational fishery landings.

North Carolina commercial fishery

The NC commercial fishery accounts for about one-third of the commercial landings along the Atlantic coast. A separate landings-at-age matrix for this component of the commercial fishery was developed from NC DMF length-age frequency sampling data collected during 1982-1994. The NC DMF program sampled the commercial fishery landings at a rate of about 100 mt of landings per 25 ages (Table C8). Lengths and ages were sampled from the summer pound net, summer long haul seine, winter gillnet, and winter trawl fisheries, and separate matrices were developed for each before summing to provide an estimate of total NC commercial fishery landings at age and mean weights at age (Tables C9-C10). For 1995, since no NC commercial samples were available, NC commercial fishery landings were assumed to have the same length and age proportions as the 1995 recreational fishery landings.

Commercial Discards

Analysis of data on bluefish catch collected by the NEFSC sea sampling program in the Gulf of Maine groundfish gillnet fishery and the Southern New England/Mid-Atlantic otter trawl fishery for 1989-1992 indicated that discards in both fisheries have comprised less than 10% of the total catch per trip. Length frequency sampling has been inconsistent, and the data are not adequate to develop an estimate of either total discard or discard at length for the 1989-1992 period. Data for the 1993-1995 period have not been evaluated.

Recreational Catch and Effort

Summary fishery statistics collected by the NMFS Marine Recreational Fishery Statistics Survey (MRFSS) are presented in Tables C11-C12. The time series of recreational catch has been revised by the MRFSS since the SAW-18 assessment (NEFSC 1994b), and the revised statistics were used in this assessment. The 1995 recreational fishery total landings (catch type A: fish landed and available for sampling, plus type B1: fish landed but not available for sampling, plus type B2: fish released alive, of which 15% are assumed to die) was about 7,200 mt (15.9 million pounds), or 8% below the 1994 landings of 7,900 mt (17.4 million pounds; Tables C1 and C11). The proportion of fish released alive has increased since 1982, peaking at 51.3% of the total catch in 1994 and 1995 (Table C12).

The length frequency sampling intensity for the recreational fishery for bluefish was calculated on the basis of metric tons of total catch per 100 lengths measured. Sampling intensity has not met the generally accepted target of 200 mt per 100 lengths measured, and in most years has been poor relative to this target level (Burns *et al.* 1983) (Table C13). The length composition of the recreational catch during 1982-1995 was estimated by 2-month sampling period (wave), state, fishing mode (shore and boat), and fishing area (inland and territorial sea, EEZ) strata by merging MRFSS intercept length frequency samples with estimated type A, B1, and B2 catches. Catch types B1 and B2 were assumed to have the same length frequency distribution as catch type A, and catch type B2 was assumed to have a hooking (discard) mortality rate of 15%, based on the study by Malchoff (1995), as modified by the ASMFC Bluefish Technical Committee.

No age structures (i.e., scales) are sampled by the MRFSS from fish captured in the recreational fishery. Recreational lengths sampled during 1982-1994 were converted to ages by applying the corresponding annual NC DMF commercial fishery age-length keys. For 1995, since no NC commercial fishery samples were available, the 1995 recreational fishery length frequency was converted to age using the 1994 NC DMF commercial fishery age-length keys (Tables C14-C15).

An initial comparison of the age frequency derived by the NC DMF keys and by the MULTIFAN method (Fournier *et al.* 1990) at SAW-18 indicated that the ages would be comparable for ages 0-3, with some divergence at older ages (NEFSC 1994b). The MULTIFAN method tended to convert larger lengths to ages based on the mean pattern of growth (which is influenced strongly by the growth pattern evident for the younger ages) and to form a large "plus group". The NC DMF keys tended to provide a smoother decline in numbers at age, improved coherence of strong and weak cohorts at age 5 and older, and a broader distribution at older ages.

A comparison of Connecticut Department of Environmental Protection (CT DEP) trawl survey age-length keys for 1984-1987 and NC DMF commercial keys using the method of Hayes (1993) was made to determine if application of the NC DMF keys would cause a serious bias in the conversion of lengths to age if applied to recreational fishery length frequencies. The method computes the probability of obtaining the observed difference between proportions at age for a given length interval in the age-length key by random chance. The method suggested no serious bias would be caused if the annual NC DMF age-length keys were used to age the recreational length data (NEFSC 1994b).

For further comparison, the recreational lengths were converted to age using both MULTIFAN and the NC DMF age-length keys to develop parallel recreational catch-at-age and mean weight-at-age matrices, and thus parallel total (commercial and recreational) catch-at-age and mean weight-at-age matrices, for the 1982-1992 time series (NEFSC 1994b). After considering the results from applying the Hayes method (1993) and upon inspection of the catch-at-age matrices developed with the alternative length-to-age conversion methods, use of the NC DMF age-length keys was judged to be the preferred approach (NEFSC 1994b). Therefore, the catch-at-age matrices compiled with the NC DMF keys were adopted as the best estimates of recreational catch at age.

Recreational Fishery-Based CPUE Indices

The intercept sample data from the MRFSS for 1982-1995 were used to develop an index of relative abundance (CPUE). Recreational fishing effort was defined as trips that caught bluefish, plus trips in which bluefish was the target species and in which some fish (of any species) were caught (CAT/TAR effort definition of SAW-18; NEFSC 1994b). For the CAT/TAR GLM (SAS 1989) standardized index, a main effects (year, state, 2-month sampling wave, and fishing mode) model accounted for about 8% of the variation in intercept catch per trip from 1982 through 1995. This standardized index suggests a general decline in bluefish abundance since 1989 (Table C16). This catch-in-numbers index was converted to a spawning stock biomass (SSB) index by applying a) the annual proportions of age 1+ fish in the recreational landings and b) the annual mean weight of the spawning age fish in the recreational landings to the index for use in age-structured population models (Table C17).

Total Catch Composition at Age

NER commercial fishery landings (Table C6), NC commercial fishery landings (Table C9), and recreational fishery landings-at-age matrices (landings plus release mortalities) (Table C14) were summed to provide an estimate of total catch at age of bluefish for 1982-1994 (Table C18). Mean weights at age in the total catch (Table C19) were calculated as a weighted mean (by number) of the mean weights at age in the component fisheries. For 1995, catch-at-length data from the NER commercial fishery, catch-at-length data from the NC commercial fisheries, and NC DMF age-length keys from the NC commercial fisheries were not available. The 1994 NC DMF commercial fishery age-length keys were used to convert the 1995 recreational length frequencies to age, and the 1995 NER and NC commercial fishery landings were assumed to have the same proportions at age as the 1995 recreational fishery landings. The 1995 total landings at age are, therefore, considered preliminary.

Research Survey Abundance and Biomass Indices

NEFSC Fall Surveys

Long-term trends in bluefish abundance were derived from stratified random bottom trawl surveys conducted by the NEFSC between Cape Hatteras and Nova Scotia. Catches of bluefish in spring surveys are low and sporadic. Bluefish are caught consistently in relatively large numbers during the fall survey, however, especially in inshore strata. Generally, over 90% of the bluefish caught in the fall inshore survey are less than 40 cm fork length and, therefore, mainly age 0 and age 1 fish. The NEFSC inshore survey indices for 1974-1995 suggest that strong year classes of bluefish recruited in 1977, 1981, 1984, and 1989, with poor recruitment occurring in 1974, 1987, 1990, 1993, and 1995 (Table C20). Mean weight per tow (kg./tow) of bluefish (ages 0+) was lowest in 1993 (0.74 kg./tow) and has remained relatively low in 1994 and 1995 (Table C21). For 1982-1995, lengths were converted to ages using the corresponding annual NC DMF commercial fishery age-length keys (Table C22).

Catches of bluefish in offshore strata (1-15, 61-76) during the fall are low and sporadic. Lengths were converted to ages using the corresponding annual NC DMF commercial fishery age-length keys.

Unlike the inshore strata set, age 0 and age 1 fish do not dominate the catches in offshore strata. There is no trend in the offshore index during the 1982-1995 period, but there is evidence of an increasing trend since 1991 (Table C23).

Connecticut DEP

A fall bottom trawl survey conducted by the Connecticut Department of Environmental Protection (CT DEP) catches bluefish at age 0 and older in Long Island Sound. Between 1984 and 1995, results from this survey suggest that strong year classes recruited to the stock in 1984-1986 and 1989, with poor year classes in 1987, 1988, 1993, and 1995 (Table C24).

Rhode Island DFW

A standardized bottom trawl survey has been conducted during the fall months in Narragansett Bay and state waters of Rhode Island Sound by the Rhode Island Division of Fish and Wildlife (RI DFW) from 1979 to 1995. An index of age 0 bluefish abundance developed from this survey (mean number per tow less than 30 cm) indicated strong year classes in 1984, 1987, 1991, 1994, and 1995, with very weak year classes in 1979 and 1992. The RI DFW has also conducted a beach seine survey consisting of 15 stations sampled during June-October between 1986 and 1995. An age 0 index developed from those data indicated strong year classes in 1987, 1990, 1991, and 1994, with poor year classes indicated in 1986, 1992, 1993, and 1995 (Table C25).

New York DEC

The New York Department of Environmental Conservation (NY DEC) has conducted a beach seine survey for striped bass in the Hudson River in which age 0 bluefish are also captured. Data from this survey suggest that strong year classes recruited to the stock in 1981-1984 and 1988, with poor year classes occurring during 1991-1995. The New York DEC has also conducted a beach seine survey within western Long Island Sound during 1986-1995. This survey suggests a decline in bluefish year class strength since 1991 (Table C25).

New Jersey BMF

The New Jersey Bureau of Marine Fisheries (BMF) has conducted a beach seine and otter trawl survey from 1988 through 1995. The seine survey adequately samples age 0 bluefish (< 25 cm), whereas the trawl survey provides an index of older bluefish abundance (ages 1+). The seine survey has shown that relatively strong year classes occurred in 1988, 1989, and 1994 (Table C25), while a weak year class was evident in the New Jersey seine survey in 1993. The New Jersey trawl survey has shown a fairly steady decline in the relative abundance of older (ages 1+) bluefish (Table C26).

Delaware DFW

The Delaware Division of Fish and Wildlife (DE DFW) has conducted a standardized bottom trawl survey (30-ft headrope trawl with 0.5-in stretched mesh) since 1980. A recruitment index (age 0, fish less than 30 cm) has been developed from these data for the 1980-1995 year classes. The index incorporates data collected during June-October (arithmetic mean number per tow), with age 0 bluefish separated from older fish by visual inspection of the length frequency. This index suggests that good year classes recruited to the stock in 1988 and 1989, with poorest recruitment occurring during 1980-1985 (Table C25).

Maryland DNR

The Maryland Department of Natural Resources (DNR) has developed bluefish juvenile indices of abundance (geometric mean number per seine haul) from the juvenile seine survey in Chesapeake Bay during 1981-1994. The Maryland seine survey indicated that strong year classes were evident in 1982, 1983, and 1985, with weak year classes in 1986-1988 and 1991-1994 (Table C25).

Virginia Institute of Marine Science

The Virginia Institute of Marine Science (VIMS) has conducted a juvenile fish survey in Virginia rivers since 1955 using trawl gear. An index of recruitment developed from these data since 1979 suggests that the strongest year classes recruited to the bluefish stock in 1981, 1984, 1989, and 1990, with poor year classes in 1979-1980, 1985-1987, 1991, and 1993. VIMS has also conducted a haul seine survey targeting juvenile striped bass in Chesapeake Bay. An index of age-0 bluefish abundance from this survey indicates strong year classes recruiting in 1981, 1983, 1985, 1987, and 1991, with poor year classes in 1986, 1992, and 1993 (Table C25).

North Carolina DMF

The NC DMF has conducted a juvenile fish trawl survey during May and June since 1979 which samples fixed stations from the Cape Fear River to the mouth of Albermarle and Currituck Sounds at depths < 2 meters. One-minute tows are made using a trawl with a 3.2-m headrope and 3.2-mm (0.13-in) mesh codend. Indices of abundance developed from this survey using data for shrimp, croaker, and spot have shown good correlation with landings for those species. For age 0 bluefish, the NC DMF juvenile fish trawl survey results suggest that strong year classes recruited in 1981, 1987, and 1989, with the poorest year classes recruiting in 1983-1984, 1986, and 1992-1994 (Table C25).

A trawl survey has been recently established (since 1987) within the Neuse and Pamlico Rivers and Pamlico Sound at depths > 2 meters. This survey uses a demersal trawl rigged with a 9.1-m headrope and 1.9-cm (0.75-in) mesh codend. An index of age-0 bluefish abundance developed from these survey data suggests that the best year classes of bluefish recruited in 1990, 1991, and 1994 (Table C25).

Summary of Recruitment Trends in Research Surveys

Indices of abundance for bluefish from research surveys were used to qualitatively detect recent trends in recruitment. Most surveys agreed that the best year classes recruited in 1981, 1984, 1989, and 1994, with poor year classes in 1992, 1993, and 1995 (Table C25).

Estimates of Mortality and Stock Size

Natural Mortality Rate (M)

At SAW-17 (NEFSC 1994a), '*the SARC suggested that values of M for bluefish in the range of 0.2 to 0.25 might be more appropriate*'[than the value of 0.35 used in some previous analyses]. The SARC has concluded that a value of M = 0.25 is consistent with the maximum age of 12 observed for bluefish, and that value of M has been used in the current assessment.

Integrated Catch-at-Age (ICA) Analysis

An age-structured analysis to estimate bluefish abundance and mortality rates during 1982-1995 was implemented in the ICA model (ICA version 1.2; Patterson and Melvin 1995) for this assessment. ICA is a multiple tuning index version of the CAGEAN model (Deriso *et al.* 1985) used for the SAW-18 bluefish assessment (NEFSC 1994b). The ICA model has the following features: a) separability in the catch at age can be assumed for a variable period at the end of the catch time series, b) up to five CPUE at age and three SSB tuning series may be used, c) a stock-recruit relationship can be estimated, d) identity (I = N), linear (I = qN), or power ($I = qN^k$) relationships can be fit between tuning indices and population estimates, e) correlated error among ages within indices can be specified, and f) iterative re-weighting of tuning indices based on inverse variance can be used. ICA tuning proceeds in two stages: 1) an initialization step (ICA1) is performed using a simple, one-dimensional minimization method to find the terminal F value in the separable part of the catch-at-age matrix that provides the lowest sum of squared residuals for the tuning indices, and 2) a full, multi-dimensional minimization of the tuning indices and the catch data for the specified separable period is performed, with iterative re-weighting and fitting of a stock-recruit relationship, if desired (ICA2). In the ICA version 1.2 used in this bluefish assessment, a separable model is fit for the period 1992-1994/95, with earlier years back-calculated from the 1992 stock size estimates using conventional VPA equations. The parameters estimated are 1) stock sizes for all true ages (0-8) in

1994/95 and for the oldest true age (age 8) in 1992-1994/95, 2) the fully recruited fishing mortality rate on the reference age (age 2, later revised to age 1) during 1992-1994/95, 3) selection at age for ages 0 and 2-7 during 1992-1994/95, and 4) catchability coefficients (q and k as required) for each tuning index. All indices were assigned a prior weight of 1.0 in the tuning. Selection on the oldest true age (age 8) was initially set at 1.0, and later revised to 0.4.

ICA results: preliminary runs

A series of preliminary ICA runs carried through the ICA1 tuning stage was made to explore the influence on results of a) tuning indices (program constraints prevent using all of the available indices simultaneously), b) the inclusion of the preliminary 1995 catch data, and c) the value of terminal selection (S) assumed for the oldest true age (age 8). In these runs, the separable model period was limited to 1992 and later years, with the reference age set at age 2. These preliminary runs indicated that the RI DFW, DE DFW, and VIMS age 0 indices were not useful in ICA tuning. Since data from the NEFSC fall offshore survey were not updated until after review of the final ICA run, the value of those data as tuning indices was not evaluated in the current ICA runs.

A baseline ICA1 run was configured with the recreational fishery CAT/TAR GLM index converted to SSB (RECSSB), the NJ BMF SSB index, the NEFSC indices (ages 0-8), the CT DEP indices (ages 0-6), the NY DEP, NJ BMF, and NC DMF age 0 indices, and catch at age for 1982-1994, with a linear catchability model used for all indices. This configuration was also run using a power catchability model for all indices. Next, runs were configured to include the preliminary 1995 catch-at-age vector and relevant survey indices. A subsequent "mixed" run used the best fitting model type (linear or power) based on inspection of the variance estimates from the previous runs (e.g., both SSB indices use power models in the mixed run, while the NEFSC indices all are tuned with a linear model). Results were sensitive to the relationship specified for the tuning indices, with the 1994 terminal F varying from 0.2 to 0.4 with 1995 catch data included.

Following the recommendations made for the SAW-22 summer flounder assessment (NEFSC 1996), the abundance estimates from the 1995 ICA model were next compared with the survey indices in a post-hoc correlation analysis. The intent was to exclude from subsequent ICA runs those indices which did not have a significant (alpha = 0.10) relationship with the ICA estimates.

The selectivities (S) estimated in ICA1 runs for the 1992-1995 period were very different from those estimated at SAW-18 for 1987-1993 using the CAGEAN model, with selectivity on ages 2-7 much lower, but selectivity on the age 9+ group much higher (S on age 9+ estimated by CAGEAN at 0.37, S on age 9+ fixed in the ICA model at 1.0). SAW-18 (NEFSC 1994b) accepted the CAGEAN selectivity values because they were reasonably close to 1.0 for ages 3 and older, except for the plus group (ranging from 0.47 for age 4 to 1.01 for age 8, before dropping to 0.37 for ages 9+). The SARC next explored the sensitivity of the ICA model to the value assumed for terminal selection, S at age 8, over the range from 0.4 to 1.0.

ICA results: final run

Results carried out through the ICA1 tuning stage showed that selectivities estimated for ages 0 and 2-7 were stable over the 0.4-1.0 range of fixed terminal S for age 8. The total variance explained by the model decreases for increasing values of S (and therefore higher F on ages 8-9+), but since the SARC felt it unlikely that selection would be very different between ages 6-7 and ages 8-9+, a value of 0.40 was assumed for the terminal S because this value was closest to the values estimated for ages 6-7. The resulting asymmetric, dome-shaped selection pattern implies that a large component of the adult bluefish stock is not fully vulnerable to the fisheries, either because of gear characteristics or spatial distribution. The SARC felt this was a reasonable conclusion given the nature of the fisheries for bluefish. During 1992-1994, recreational hook and line and commercial gillnet fisheries have accounted for 86% of the total bluefish landings. For both of these gear types, large fish (e.g., ages 3 and older) would be expected to be less vulnerable to capture than small fish (e.g., age 0-2). A final run with terminal S = 0.40 was carried through the ICA2 tuning stage and served as the basis for estimates of bluefish stock size and fishing mortality rates for 1982-1995 (Table C27).

The ICA model indicates that fully recruited (S = 1.0, age 1) fishing mortality rates on bluefish increased from 0.13 in 1985 to 0.25 in 1987, decreased to 0.18 by 1990, and then increased to 0.51 in 1992 before falling to 0.38-0.40 in 1994-1995 (Figure C1). Recruitment at age 0 varied from 68 to 82 million fish during 1982-1984, but has since declined substantially. Geometric mean recruitment was about 35 million fish during 1982-1995, but recruitment during 1992-1995 averaged only about 17 million fish (Figure C2). Thus, although catches have dropped steadily over the last decade, F has risen because low recruitment since 1989 has resulted in reduced stock abundance (Figures C1-C2).

Precision of estimates of stock size and fishing mortality

The version of ICA currently available at the NEFSC does not have the capability to provide bootstrapped estimates of spawning stock biomass and fishing mortality. Alternatively, estimates of the precision (standard error) of these quantities were computed from the variance/covariance matrix of the ICA2 multivariate non-linear least squares solution. These estimates are likely to indicate greater precision than would bootstrap estimates. The resulting probability distributions of spawning stock biomass and fishing mortality rate in 1995 are presented in Figures C3 and C4.

Biological Reference Points

Revised biological reference points for bluefish were calculated with the Thompson and Bell (1934) model. Input data included M = 0.25, mean weights at age for ages 0-12 in the stock and fishery averaged for 1992-1995, and the asymmetric, dome-shaped partial recruitment vector estimated by the ICA model for 1992-1995. The Thompson and Bell yield-per-recruit analysis indicated that $F_{0.1} = 0.31$, $F_{30\%} = 0.42$, $F_{MAX} = 0.47$, and $F_{20\%} = 0.59$ (Table C28, Figure C5). The use of the dome-shaped selection pattern in the yield-per-recruit analysis has resulted in the estimation of biological reference points that are higher than those from the last assessment in which a "saddle-shaped" selection pattern was estimated.

Although the reference point currently specified in the Bluefish FMP is F_{MSY}, estimated to be 0.20 at SAW-18 (NEFSC 1994b) (not recalculated in the present assessment), draft Amendment 1 to the FMP proposes new reference points based on maximum spawning potential (MSP). $F_{30\%}$ is proposed as the target fishing mortality rate and $F_{20\%}$ as the threshold fishing mortality rate, beyond which overfishing would be defined as occurring.

Projections

Projections of landings and spawning stock biomass were made for 1996-1998. Projections were started from the population sizes estimated for 1995 using the asymmetric, domed-shaped selection pattern estimated for 1992-1995 by the ICA model. The short-term geometric mean (1992-1995) recruitment level of 17.0 million fish at age 0 per year was assumed for 1996-1998. Fishing mortality in 1996 was assumed to continue at the level estimated for 1995 (F = 0.40).

If fishing mortality rates remain at 0.40 or greater in 1997 and 1998, SSB will continue to decline to record lows in 1997 and 1998, with landings of 10,900-14,400 mt by 1998. If fishing mortality is reduced to $F_{MSY} = 0.20$ or to $F_{STAB} = 0.06$ in 1997-1998, SSB should stabilize, but landings would be reduced considerably, falling to 2,000-6,200 mt (Table C29, Figure C6).

SARC Discussion

Bluefish spawning stock biomass declined dramatically from 1982 to 1995, reaching an historic low in 1995. Assessment results suggest that a consistent decline in recent recruitment largely accounts for the decline in stock biomass. The best recent year class recruited to the stock in 1989, with below- average

(1982-1995) recruitment produced since 1989. The 1993 and 1995 year classes are the poorest of the 1982-1995 period. Fishing mortality rates (F) based on ICA model results were not high in earlier years (1982-1990), but recently have substantially exceeded F_{MSY} = 0.20. Fishing mortality peaked in 1992 at 0.51, and was 0.40 in 1995. Increases in F in recent years indicate that the stock is over-exploited, according to the current overfishing definition in the Bluefish FMP, and significant reduction in fishing mortality will be required to halt the decline in spawning stock biomass.

The asymmetric, dome-shaped selection pattern estimated in the age-structured analysis (ICA model) implies that the adult bluefish stock (age 2 and older) is not fully vulnerable. The estimation of a dome-shaped selection arises from the characteristics of the catch-at-length/age data. The dome-shaped selection pattern is in line with the nature of the fisheries (recreational hook and line, commercial gillnet) that account for most of the landings. The use of the dome-shaped selection pattern in the yield-per-recruit analysis provides estimates of the reference points $F_{20\%}$ and $F_{30\%}$ proposed in Amendment 1 of the FMP that are significantly higher than the current reference point (F_{MSY}) estimated in the SAW-18 assessment. Although $F_{20\%}$ and $F_{30\%}$ are appropriate long-term, equilibrium reference points, the SARC felt they were not sufficiently conservative at the present time given the declining trend in SSB and recruitment and their current record-low levels.

The short-term average recruitment level used in the projections (1992-1995; geometric mean of 17.0 million age 0 fish) is 48% of the long-term average (1982-1995; geometric mean of 35.4 million age 0 fish). Projections based on a short-term average were judged to be most useful for providing management advice because recruitment has not exceeded 30 million fish since 1989.

The SARC reviewed a brief summary of estimates of fishing mortality and stock size based on analyses of American Littoral Society (ALS) angler tagging data and a multiple tuning index modified DeLury model incorporating those tagging data as a tuning measure. Since neither the Coastal/Pelagic Subcommittee nor the SARC had an opportunity to review those analyses in depth, the SARC consided the ALS tagging and multiple index DeLury results to be preliminary.

The tagging data and DeLury analyses provided much higher estimates of fishing mortality than the ICA model accepted as the basis for the assessment. The ALS tag return data are sparse, with return rates of 0.5% to 3.6% per year and a total of 247 of 10,343 (2.4%) tags recovered during the 1984-1995 time series. Fishing mortality estimates from tagging assume that all fish tagged, except those accounted for by the tag loss rate, are fully available to the fishery for recapture (this assumption also applies to the fully recruited fish in the DeLury model). This assumption is fundamentally different from the conclusion drawn from the age-structured population model (ICA analysis), i.e. that a large component of the adult bluefish stock is not fully vulnerable to the fisheries. The high estimates of F from tagging are contradicted by the continued presence of large/old fish in the recreational and commercial fishery length/age data. The SARC recommends that age-based tag recovery models be considered in future assessments, as this may help address the question of whether all age classes of bluefish are vulnerable to tagging and recapture. Estimates of mortality from tagging are potentially valuable, however, because they are independent of the ICA age-structured analysis. The SARC also appreciates and encourages continued development by ASMFC scientists of the multiple tuning index modified DeLury method.

Given that the survivability of bluefish (i.e., relative recruitment success; R/SSB) has apparently declined, the SARC briefly reviewed two working papers relevant to term of reference d). The first, Crecco MS 1996, discussed the hypothesis that adult bluefish have shifted their distribution offshore in recent years. There is some evidence in the pattern of commercial landings and effort that adult bluefish have been displaced further offshore in recent years. The second working paper, Terceiro MS 1996, investigated the relationships among several factors that might influence bluefish distribution and abundance.

Exploratory analyses suggest that bluefish recruitment may be correlated with biotic and environmental variables. It is not clear if these correlations indicate common responses to environmental conditions or the abundance of other species or simply coincidental trends with no underlying functional relationship. Both working papers could prove valuable as the basis for developing hypotheses to be explored in future work.

Research Recommendations

- The intensity of biological sampling of the NER commercial and coastwide recreational fisheries (expressed as mt/100 lengths) has historically been low and has worsened since 1989 for the NER commercial fishery. A substantial improvement in biological sampling of the NER commercial and, particularly, the recreational fisheries, and collection of age samples from the recreational fishery, are critical to improving the precision of the assessment.

- The assessment relies on age-length keys compiled by the NC DMF from samples of the North Carolina commercial fisheries. The SARC recommends that any archived age data for bluefish be aged (e.g., NER commercial fishery and NEFSC research survey data) and used to supplement the NC DMF keys in future assessments.

- The analysis of ALS tag data assumes that the tag loss rate for bluefish is similar to that for striped bass, plus 25% to account for the potential difficulties in handling this species during tagging. The SARC recommends a study of tag mortality and retention rates for the ALS dorsal loop and other tags used for bluefish to improve the level of confidence in this assumption.

- The SARC recommends testing the sensitivity of the bluefish assessment to assumptions concerning age-varying M, levels of age 0 discard, and the selection pattern.

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Table C1. Estimated bluefish catch: commercial landings, recreational landings, recreational catch, and foreign landings, Maine - Florida, east coast (metric tons). Recreational landings include catch type A (fish landed and available for sampling), type B1 (fish landed but not available for sampling), and 15% of type B2 (fish released alive, assuming a 15% discard mortality rate). Recreational catch includes catch types A and B1, plus all catch type B2. Total landings include commercial landings, recreational landings, and foreign landings. Total catch includes commercial landings, recreational catch, and foreign landings.

Year	Commercial landings	Foreign landings	Recreational landings	Recreational catch	Total landings	Total catch
1960	1,251	0	N/A	11,475[1]	N/A	12,726
1961	1,401	0	N/A	N/A	N/A	N/A
1962	2,256	0	N/A	N/A	N/A	N/A
1963	2,123	0	N/A	N/A	N/A	N/A
1964	1,743	0	N/A	N/A	N/A	N/A
1965	1,847	0	N/A	20,528[1]	N/A	22,375
1966	2,172	0	N/A	N/A	N/A	N/A
1967	1,671	0	N/A	N/A	N/A	N/A
1968	2,159	0	N/A	N/A	N/A	N/A
1969	2,445	0	N/A	N/A	N/A	N/A
1970	2,952	0	N/A	27,024[1]	N/A	29,976
1971	2,624	23	N/A	N/A	N/A	N/A
1972	3,115	18	N/A	N/A	N/A	N/A
1973	4,556	214	N/A	N/A	N/A	N/A
1974	4,538	99	N/A	N/A	N/A	N/A
1975	4,502	103	N/A	N/A	N/A	N/A
1976	4,547	1	N/A	N/A	N/A	N/A
1977	4,802	4	N/A	N/A	N/A	N/A
1978	5,629	35	N/A	N/A	N/A	N/A
1979	4,983	28	58,556	63,759	63,567	68,770
1980	6,858	23	63,886	69,612	70,767	76,493
1981	7,466	71	43,935	47,972	51,472	55,509
1982	6,996	77	36,009	38,201	43,082	45,274
1983	7,166	33	41,217	45,707	48,416	52,906
1984	5,381	68	31,226	34,788	36,675	40,237
1985	6,124	18	24,320	27,149	30,462	33,291
1986	6,657	28	43,449	50,905	50,134	57,590
1987	6,579	2	34,961	42,834	41,542	49,415
1988	7,162	0	22,906	28,759	30,068	35,921
1989	4,740	0	18,699	23,879	23,439	28,619
1990	6,246	0	14,789	20,069	21,035	26,315
1991	6,160	0	16,190	23,114	22,350	29,274
1992	5,214	0	11,973	17,446	17,187	22,660
1993	4,664	0	9,991	14,547	14,655	19,211
1994	4,284	0	7,869	12,523	12,153	16,807
1995	3,353	0	7,248	11,879	10,601	15,232

[1]Marine angling survey estimates, adjusted as per Boreman (1983) - these surveys used a different methodology than the MRFSS and are not directly comparable to recreational catch estimates since 1979.

Table C2. Bluefish commercial landings by State (mt).

Year	ME	NH	MA	RI	CT	NY	NJ	DE	MD	VA	NC	SC	GA	FL	Total
1979	15	1	362	170	25	792	719	18	147	1,243	884	1	*	606	4,983
1980	44	1	315	166	22	675	635	74	198	1,278	2,469	1	0	978	6,858
1981	44	20	371	160	142	581	832	89	188	1,061	2,998	1	*	978	7,466
1982	75	30	406	270	136	781	898	232	131	1,176	1,946	4	*	911	6,996
1983	77	14	454	235	31	765	873	132	150	689	3,060	5	0	680	7,166
1984	22	8	318	462	45	742	767	71	83	525	1,614	1	0	719	5,381
1985	41	10	362	767	82	968	902	85	231	749	1,635	*	0	288	6,124
1986	48	28	709	518	86	733	1,362	181	207	686	1,565	4	1	528	6,657
1987	47	58	362	537	79	709	1,149	161	165	536	2,069	1	1	702	6,579
1988	4	10	366	464	46	510	1,126	95	468	1,186	2,286	1	1	596	7,162
1989	35	62	562	549	88	256	718	47	125	349	1,493	1	0	453	4,740
1990	24	89	546	537	81	731	984	65	129	491	2,077	*	0	488	6,246
1991	56	58	343	676	117	716	1,110	153	106	373	1,778	*	0	672	6,160
1992	39	103	376	703	131	677	997	42	93	269	1,288	1	0	495	5,214
1993	8	73	379	542	77	703	994	27	60	47	1,255	0	0	499	4,664
1994	24	125	543	409	69	668	858	15	73	266	808	3	0	423	4,284
1995	9	85	245	350	53	575	385	17	27	12	1,365	*	*	229	3,353

Table C3. Distribution of Northeast region commercial fishery landings by gear type.

Year	Landings (mt) by gear type					
	Trawl	Gillnet	Pound net	Seine	Other	Total
1982	1,535	2,193	337	0	70	4,135
1983	1,317	1,719	293	0	91	3,420
1984	1,331	1,482	140	25	66	3,043
1985	2,150	1,517	303	141	85	4,197
1986	1,545	1,674	644	449	247	4,558
1987	1,084	1,914	513	28	265	3,803
1988	1,080	2,206	608	131	201	4,225
1989	870	1,737	113	7	64	2,791
1990	1,157	2,026	275	4	215	3,677
1991	1,243	1,819	249	228	169	3,708
1992	1,232	1,608	245	41	122	3,248
1993	883	1,665	467	166	203	3,384

Year	Percentage of landings					
	Trawl	Gillnet	Pound net	Seine	Other	Total
1982	37.1	53.0	8.2	0.0	1.7	100.0
1983	38.5	50.3	8.6	0.0	2.7	100.0
1984	43.7	48.7	4.6	0.8	2.2	100.0
1985	51.2	36.2	7.2	3.4	2.0	100.0
1986	33.9	36.7	14.1	9.8	5.4	100.0
1987	28.5	50.3	13.5	0.7	7.0	100.0
1988	25.6	52.2	14.4	3.1	4.8	100.0
1989	31.2	62.2	4.0	0.3	2.3	100.0
1990	31.5	55.1	7.5	0.1	5.9	100.0
1991	33.5	49.1	6.7	6.2	4.6	100.0
1992	37.9	49.5	7.5	1.3	3.7	100.0
1993	26.1	49.2	13.8	4.9	0.6	100.0

Table C4. Distribution of North Carolina commercial fishery landings by gear type.

Year	Landings (mt) by gear type					
	Trawl	Gillnet	Pound net	Seine	Other	Total
1982	723	517	101	236	372	1,949
1983	1,686	937	39	181	217	3,060
1984	494	645	41	164	270	1,614
1985	402	672	60	241	259	1,634
1986	302	790	36	221	216	1,565
1987	212	1,262	50	249	296	2,069
1988	547	1,158	89	225	267	2,286
1989	290	882	18	155	148	1,493
1990	116	1,455	25	275	206	2,077
1991	116	1,094	26	264	278	1,778
1992	339	646	11	196	95	1,287
1993	169	854	13	70	149	1,255
1994	24	648	7	54	99	832

Year	Percentage of landings					
	Trawl	Gillnet	Pound net	Seine	Other	Total
1982	37.1	26.5	5.2	12.1	19.1	100.0
1983	55.1	30.6	1.3	5.9	7.1	100.0
1984	30.6	40.0	2.5	10.2	16.7	100.0
1985	24.6	41.1	3.7	14.7	15.9	100.0
1986	19.3	50.5	2.3	14.1	13.8	100.0
1987	10.2	61.0	2.4	12.0	14.3	100.0
1988	23.9	50.7	3.9	9.8	11.7	100.0
1989	19.4	59.1	1.2	10.4	9.9	100.0
1990	5.6	70.1	1.2	13.2	9.9	100.0
1991	6.5	61.5	1.5	14.8	15.6	100.0
1992	26.3	50.2	0.9	15.2	7.4	100.0
1993	13.5	68.0	1.0	5.6	11.9	100.0
1994	2.9	77.9	0.8	6.5	11.9	100.0

Table C5. Summary of NEFSC sampling of the NER (ME-VA) commercial fishery for bluefish, 1982-1993. Age samples are currently archived. NEFSC weighout landings are those characterized directly by length frequency sample data. Total NER landings include weighout plus general canvas data. Length frequency distributions based on NEFSC weighout landings are raised to NER total landings.

Year	Samples	Lengths	Ages	Weighout landings (mt)	Total landings (mt)	Intensity (mt/100 lengths)
1982	9	942	141	1,622	4,135	439
1983	20	1,900	401	1,515	3,420	180
1984	22	2,045	456	1,477	3,043	149
1985	18	1,581	376	2,087	4,197	265
1986	20	1,838	445	3,411	4,558	248
1987	11	1,105	250	2,847	3,803	344
1988	20	1,961	450	2,401	4,225	215
1989	6	590	150	1,953	2,791	473
1990	4	402	52	2,765	3,677	915
1991	2	201	51	2,792	3,708	1,845
1992	4	400	50	2,839	3,248	812
1993	2	200	25	2,059	2,159	1,080

Table C6. NER (Maine to Virginia) commercial fishery landings at age for bluefish ('000). The 1982-1989 lengths were converted to age using NC DMF annual age-length keys from the NC winter fishery. The 1990-1994 landings were assumed to have the same age composition as the NC winter fishery landings.

	Age												
Year	0	1	2	3	4	5	6	7	8	9	10	11	Total
1982	505	994	848	846	51	56	49	14	4	0	0	0	3,368
1983	2	364	1,498	369	68	27	43	31	15	2	0	3	2,422
1984	247	1,184	2,358	195	29	19	12	10	3	1	0	0	4,059
1985	83	640	790	375	400	40	53	60	40	20	0	1	2,503
1986	74	2,069	2,025	70	32	139	87	35	21	9	0	0	4,561
1987	0	47	488	1,064	292	22	44	25	10	0	0	0	1,993
1988	230	318	717	323	398	220	98	75	23	9	9	0	2,420
1989	49	490	713	53	62	201	113	60	26	0	4	0	1,770
1990	341	624	71	37	53	110	376	105	137	4	0	0	1,858
1991	569	1,017	2,465	10	15	48	86	163	86	1	1	0	4,461
1992	976	4,858	203	124	42	202	2	2	3	2	0	0	6,414
1993	32	51	384	63	58	19	67	130	125	23	5	4	961
1994	167	524	165	0	57	285	131	28	85	54	0	0	1,496

Table C7. NER (Maine to Virginia) commercial fishery landings mean weights at age (kg) for bluefish.

	Age												
Year	0	1	2	3	4	5	6	7	8	9	10	11	All
1982	0.198	0.621	1.159	1.979	2.853	4.511	5.297	5.684	5.194	-	-	-	1.228
1983	0.416	0.852	0.981	1.980	3.054	4.296	5.715	6.354	6.751	7.870	-	7.449	1.410
1984	0.422	0.610	0.682	1.561	2.381	4.410	5.331	6.068	6.378	7.030	-	-	0.749
1985	0.430	0.562	0.882	2.113	2.787	3.552	5.276	6.174	6.407	6.755	-	7.247	1.677
1986	0.583	0.689	0.727	2.024	3.199	4.201	4.621	5.398	6.284	6.816	-	-	0.999
1987	0.427	0.771	0.992	1.897	2.575	3.976	5.088	5.615	5.887	-	-	-	1.908
1988	0.270	0.428	0.856	1.686	2.769	3.507	4.368	5.017	5.858	6.192	5.645	-	1.766
1989	0.347	0.509	0.649	1.947	3.552	4.042	4.162	4.719	5.580	-	7.247	-	1.576
1990	0.343	0.569	0.864	1.782	2.591	3.565	3.854	4.040	4.710	7.710	-	-	1.811
1991	0.334	0.300	0.502	1.764	3.251	3.578	4.435	5.421	5.252	7.710	6.928	-	0.671
1992	0.214	0.381	1.113	1.745	2.333	2.980	4.145	4.731	4.981	7.710	-	-	0.507
1993	0.280	0.310	0.68	1.520	2.160	2.120	5.620	6.380	6.700	7.390	7.230	7.230	2.214
1994	0.290	0.350	0.750	0.960	3.740	3.550	3.630	5.000	5.980	6.400	-	-	1.971

Table C8. Summary of NC DMF sampling of the NC commercial fishery for bluefish.

Year	Sampled ages	North Carolina commercial landings (mt)	Sampling intensity (mt/25 ages)
1982	490	1,946	99
1983	596	3,060	129
1984	854	1,614	47
1985	548	1,635	75
1986	437	1,565	89
1987	381	2,069	136
1988	346	2,286	166
1989	320	1,493	117
1990	372	2,077	140
1991	279	1,778	159
1992	606	1,288	53
1993	693	1,255	45
1994	517	832	40

Table C9. NC commercial fishery landings at age for bluefish. This matrix is a sum of component matrices from the NC landings from pound nets, long haul seines, gillnets, and trawls. Landings from SC, GA, and FL are included in the gillnet landings.

	Age												
Year	0	1	2	3	4	5	6	7	8	9	10	11	Total
1982	2,621	1,464	42	17	4	17	45	57	42	18	3	1	4,331
1983	647	1,277	592	66	51	190	191	86	32	1	0	0	3,134
1984	553	583	308	20	36	145	79	45	19	0	2	0	1,790
1985	551	922	56	19	38	55	127	39	25	4	0	1	1,837
1986	870	744	178	4	24	126	64	51	27	9	1	0	2,097
1987	699	894	323	146	105	82	151	60	12	3	0	0	2,474
1988	287	323	163	38	100	182	14	224	50	3	0	0	1,385
1989	300	424	92	33	78	173	46	44	12	5	0	0	1,208
1990	430	721	87	24	33	68	232	65	84	2	0	0	1,747
1991	505	977	1,562	6	9	28	50	95	50	1	1	0	3,283
1992	511	2,798	156	63	20	98	1	1	1	1	0	0	3,649
1993	315	136	275	36	33	11	38	74	71	13	3	2	1,008
1994	232	280	67	0	22	111	51	11	33	21	0	0	829

Table C10. NC commercial fishery mean weights at age for bluefish.

	Age												
Year	0	1	2	3	4	5	6	7	8	9	10	11	All
1982	0.307	0.603	1.597	2.357	3.123	4.293	5.100	5.468	6.221	7.000	6.928	7.710	0.661
1983	0.236	0.391	0.903	1.866	2.852	3.931	4.733	5.104	5.936	7.000	-	-	1.195
1984	0.249	0.489	0.840	1.330	3.393	4.655	5.467	5.835	6.506	-	6.500	-	1.304
1985	0.207	0.404	0.759	1.816	2.545	4.530	4.729	5.734	5.981	6.800	-	7.710	1.045
1986	0.308	0.487	0.860	2.602	3.275	3.944	4.235	4.608	6.015	6.009	6.123	-	1.000
1987	0.217	0.316	0.924	1.617	3.246	4.035	4.837	5.197	6.250	7.250	-	-	1.121
1988	0.288	0.533	0.842	1.745	2.445	3.386	6.100	4.960	5.350	6.500	-	-	2.024
1989	0.280	0.487	0.734	1.819	3.130	4.261	4.705	5.398	5.670	4.989	-	-	1.611
1990	0.255	0.599	0.932	1.821	2.598	3.566	3.854	4.041	4.710	7.700	-	-	1.469
1991	0.271	0.350	0.526	1.764	3.251	3.578	4.432	5.421	5.252	7.710	6.928	-	0.746
1992	0.212	0.375	0.960	1.725	2.333	2.980	4.145	4.731	4.981	7.710	-	-	0.487
1993	0.230	0.500	0.690	1.520	2.160	2.120	5.620	6.380	6.700	7.390	7.230	7.230	1.760
1994	0.220	0.370	0.750	1.420	3.740	3.550	3.630	5.000	5.980	6.400	-	-	1.520

Table C11. MRFSS estimated total weight (mt) of bluefish caught by recreational fishermen. Shore fishing mode includes catch taken from beaches, banks, and man-made structures; P/C boat fishing mode includes catch taken from party/charter boats; P/R boat fishing mode includes catch taken from private/rental boats. For annual totals, numbers of fish released alive (catch type B2) are also totaled and expressed as a percentage of the total catch. Total mortality includes catch type A (fish landed and available for sampling), type B1 (fish landed but not available for sampling), and 15% of type B2 (fish released alive, assuming a 15% discard mortality rate).

Region/ mode	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
ME-CT														
Shore	633	2,380	828	1,263	2,781	1,452	496	837	1,653	2,421	952	804	701	894
P/C boat	14,900	9,094	4,423	3,071	6,749	941	928	1,348	784	1,085	1,153	1,966	1,756	1,305
P/R boat	3,792	5,273	4,038	4,244	11,736	9,287	5,116	4,435	4,354	5,325	4,492	3,511	3,508	2,722
Total	19,325	16,747	9,289	8,578	21,266	11,680	6,540	6,620	6,791	8,831	6,597	6,281	5,965	4,921
NY-VA														
Shore	1,873	4,056	1,608	2,266	4,504	1,232	1,105	1,553	1,294	1,875	773	475	622	418
P/C boat	8,006	6,518	6,895	5,814	6,718	8,175	2,693	4,094	1,941	3,081	2,339	1,577	1,257	1,419
P/R boat	5,869	10,150	11,596	6,758	15,232	17,704	13,476	8,563	7,854	6,662	5,818	4,351	2,843	3,478
Total	15,748	20,724	20,099	14,838	26,454	27,111	17,274	14,210	11,089	11,618	8,930	6,403	4,722	5,315
NC-FL														
Shore	1,018	1,819	2,625	1,019	1,244	1,365	3,005	1,871	1,237	1,411	864	1,025	1,312	1,183
P/C boat	695	4,294	1,649	977	330	887	244	102	49	193	100	53	36	81
P/R boat	1,415	2,123	1,126	1,737	1,611	1,791	1,696	1,076	903	1,061	955	785	488	379
Total	3,128	8,236	5,400	3,733	3,185	4,043	4,945	3,049	2,189	2,665	1,919	1,863	1,836	1,643
Coast														
Shore	3,524	8,255	5,061	4,548	8,529	4,049	4,606	4,261	4,184	5,707	2,589	2,304	2,635	2,495
P/C boat	23,601	19,906	12,967	9,862	13,797	10,003	3,865	5,544	2,774	4,359	3,592	3,596	3,049	2,805
P/R boat	11,076	17,546	16,760	12,739	28,579	28,782	20,288	14,074	13,111	13,048	11,265	8,647	6,839	6,579
Total	38,201	45,707	34,788	27,149	50,905	42,834	28,759	23,879	20,069	23,114	17,446	14,547	12,523	11,879
Total B2	2,579	5,282	4,191	3,328	8,772	9,262	6,886	6,094	6,212	8,146	6,439	5,360	5,475	5,448
Landed	35,622	40,425	30,597	23,821	42,133	33,572	21,873	17,785	13,857	14,968	11,007	9,187	7,048	6,431
Discard	387	792	629	499	1,316	1,389	1,033	914	932	1,222	966	804	821	817
Total mortality	36,009	41,217	31,226	24,320	43,449	34,961	22,906	18,699	14,789	16,190	11,973	9,991	7,869	7,248

Table C12. MRFSS estimated total number ('000) of bluefish caught by recreational fishermen. Shore fishing mode includes catch taken from beaches, banks, and man-made structures; P/C boat fishing mode includes catch taken from party/charter boats; P/R boat fishing mode includes catch taken from private/rental boats. For annual totals, numbers of fish released alive (catch type B2) are also totaled and expressed as a percentage of the total catch. Total mortality includes catch type A (fish landed and available for sampling), type B1 (fish landed but not available for sampling), and 15% of type B2 (fish released alive, assuming a 15% discard mortality rate).

Region/ mode	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
ME-CT														
Shore	4,301	2,175	2,238	2,155	1,901	2,283	512	430	1,092	2,268	866	365	717	569
P/C boat	3,196	3,336	1,518	1,482	2,030	418	263	339	189	345	434	609	434	376
P/R boat	2,598	1,679	1,730	2,072	4,506	3,840	1,536	1,324	1,575	2,232	1,730	1,223	984	1,014
Total	10,095	7,190	5,486	5,709	8,437	6,541	2,311	2,093	2,856	4,845	3,030	2,197	2,135	1,959
NY-VA														
Shore	3,237	5,041	6,329	3,825	6,482	3,641	897	4,968	2,238	4,946	1,008	1,133	2,071	1,026
P/C boat	3,210	3,812	3,373	3,677	3,280	3,936	850	1,866	1,539	2,064	1,224	779	923	932
P/R boat	4,829	7,013	5,473	5,253	8,698	9,741	5,571	5,269	5,925	4,030	3,408	2,604	3,196	3,155
Total	11,276	15,866	15,175	12,755	18,460	17,318	7,318	12,103	9,702	11,040	5,640	4,516	6,190	5,113
NC-FL														
Shore	2,915	2,572	3,670	2,080	1,888	1,686	2,075	2,409	2,271	1,329	1,255	1,865	2,517	2,436
P/C boat	863	1,321	425	473	291	257	125	127	52	70	44	63	71	126
P/R boat	2,071	3,188	1,752	1,457	1,335	1,801	1,536	1,067	1,555	1,008	1,382	1,056	923	779
Total	5,849	7,081	5,847	4,010	3,514	3,744	3,736	3,603	3,878	2,407	2,681	2,984	3,511	3,341
Coast														
Shore	10,453	9,788	12,237	8,060	10,271	7,610	3,484	7,807	5,601	8,543	3,129	3,363	5,305	4,031
P/C boat	7,269	8,469	5,316	5,632	5,601	4,611	1,238	2,332	1,780	2,479	1,702	1,451	1,428	1,434
P/R boat	9,498	11,880	8,955	8,782	14,539	15,382	8,643	7,660	9,055	7,270	6,520	4,883	5,103	4,948
Total	27,220	30,137	26,508	22,474	30,411	27,603	13,365	17,799	16,436	18,292	11,351	9,697	11,836	10,413
Total B2	3,497	5,254	5,710	3,228	5,970	6,527	3,460	5,037	5,081	6,349	4,232	4,142	6,076	5,345
Percent B2	12.8	17.4	21.5	14.4	19.6	23.6	25.9	28.3	30.9	34.7	37.3	42.7	51.3	51.3
Total mortality	24,248	25,671	21,655	19,730	25,337	22,055	10,424	13,518	12,117	12,895	7,754	6,176	6,671	5,870

Table C13. Summary of MRFSS sampling of the recreational fishery for bluefish.

Year	Lengths	Estimated total catch (mt)	Sampling intensity (mt/100 lengths)
1982	3,715	38,201	1,028
1983	5,325	45,707	858
1984	4,216	34,788	825
1985	6,699	27,149	405
1986	5,232	50,905	973
1987	5,492	42,834	780
1988	3,017	28,759	953
1989	8,204	23,879	291
1990	7,242	20,069	277
1991	6,705	23,114	345
1992	5,047	17,446	346
1993	3,951	12,787	324
1994	3,999	12,523	313
1995	2,709	11,879	439

Table C14. Recreational fishery (Maine to Florida) catch at age ('000) for bluefish. Catch type B2 (catch released alive) included with a hooking mortality rate of 15%. Lengths converted to age using NC DMF commercial fishery annual age-length keys; 1995 recreational lengths converted using 1994 age-length key.

Year	Age													Total
	0	1	2	3	4	5	6	7	8	9	10	11	12	
1982	8,000	7,267	1,968	1,587	745	1,151	1,089	747	632	836	122	63	41	24,248
1983	4,090	5,985	6,586	2,605	863	1,122	1,596	1,031	641	853	93	159	47	25,671
1984	6,240	5,030	4,052	1,835	842	594	718	717	535	869	81	95	47	21,655
1985	4,022	4,891	4,949	2,540	892	425	764	352	375	450	36	0	34	19,730
1986	4,195	5,238	6,536	2,734	1,000	1,447	1,067	963	1,141	959	57	0	0	25,337
1987	2,407	4,473	4,369	4,564	1,618	981	1,489	1,032	645	445	32	0	0	22,055
1988	1,180	1,410	1,644	1,225	1,496	1,209	749	656	343	319	156	9	28	10,424
1989	2,933	4,467	2,282	857	242	752	611	542	500	268	38	7	19	13,518
1990	1,954	5,833	1,675	626	296	254	526	263	292	381	7	7	3	12,117
1991	2,620	3,281	3,388	1,586	286	149	426	631	367	130	17	10	4	12,895
1992	649	1,935	1,357	2,177	519	180	170	306	304	145	5	5	2	7,754
1993	823	1,843	881	480	923	621	149	92	158	156	48	2	0	6,176
1994	1,567	2,333	1,078	367	217	452	191	35	189	229	9	4	0	6,671
1995	525	2,463	1,377	249	167	409	221	65	237	143	10	4	0	5,870

Table C15. Recreational fishery (Maine to Florida) mean weights at age (kg) for bluefish. Lengths converted to age using NC DMF commercial fishery annual age-length keys; 1995 recreational lengths converted using 1994 age-length key.

	Age													
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	All
1982	0.079	0.451	1.655	2.094	3.226	4.217	4.937	5.801	6.681	8.832	7.810	8.212	8.193	1.675
1983	0.073	0.402	0.997	2.177	3.189	4.502	5.673	6.298	6.910	8.906	8.404	7.912	8.404	2.039
1984	0.080	0.350	1.080	1.867	2.909	4.443	5.676	6.297	7.204	8.845	7.235	8.404	8.404	1.689
1985	0.082	0.377	0.981	1.900	2.844	3.963	5.091	6.151	6.918	8.447	8.404	-	7.812	1.471
1986	0.072	0.412	1.358	2.327	3.145	4.343	4.903	5.719	6.793	8.076	7.812	-	-	2.115
1987	0.089	0.287	1.219	2.064	3.008	3.918	4.995	5.930	6.515	8.582	7.812	-	-	2.118
1988	0.119	0.371	1.079	2.154	2.882	3.600	4.629	5.250	6.263	7.657	6.294	8.404	7.908	2.526
1989	0.106	0.256	1.195	2.140	3.818	4.088	4.821	5.606	6.132	7.770	7.903	7.247	8.206	1.596
1990	0.181	0.478	0.880	1.726	3.421	4.587	5.163	5.652	5.938	7.435	8.404	8.404	8.404	1.381
1991	0.070	0.338	0.918	1.732	2.772	4.152	5.128	5.872	6.327	7.694	7.675	7.577	8.033	1.403
1992	0.055	0.416	1.037	1.898	2.857	3.818	5.123	5.793	5.954	7.893	7.988	7.988	8.404	1.841
1993	0.149	0.601	1.151	2.652	2.787	3.293	4.360	6.014	6.175	7.099	6.854	6.202	-	1.391
1994	0.095	0.412	0.925	1.880	2.813	3.919	4.487	5.850	6.998	8.899	6.443	6.711	-	0.804
1995	0.168	0.436	0.982	1.734	2.849	4.058	4.696	5.652	6.393	7.019	6.435	6.711	-	1.034

Table C16. General Linear Model (GLM) of recreational fishery (MRFSS 1982-1995) intercept catch (types A+B1+B2) per trip data to develop standardized index of abundance. Includes trips with bluefish catch and trips with zero bluefish catch but which targeted bluefish (CAT/TAR index). Variation in log-transformed catch per trip (LOGCA) is modeled with year (YR), state (ST), two-month sampling period (WAVE), and fishing mode (MODE) as main effects, with no interactions. The corrected, re-transformed YR parameter estimates are indices of stock numbers (total number of fish caught per trip). Indices are normalized to the 1993 value for comparison with SAW-18 indices (NEFSC 1994b).

Dependent variable: LOGCA

Source	DF	SS	MSE	F	PR > F	R-Square
Model	33	5638.2	170.9	263.1	0.0001	0.08
Error	98286	63823.6	0.6			
Total	98286	9461.7				

Model SS

Variable	DF	Type III SS	F	PR > F
YR	13	1158.4	137.2	0.0001
ST	13	1679.6	199.0	0.0001
WAVE	5	102.3	31.5	0.0001
MODE	2	2088.0	1607.8	0.0001

Table C16. (Continued)

Corrected, re-transformed YR parameter estimates: Normalized to 1993 value

Year	Lower estimate	Upper 95% CI	95% CI
1982	1.539	1.577	1.501
1983	1.153	1.142	1.165
1984	1.277	1.270	1.284
1985	1.381	1.369	1.392
1986	1.258	1.254	1.262
1987	1.332	1.327	1.337
1988	1.095	1.091	1.099
1989	1.206	1.202	1.211
1990	1.184	1.183	1.184
1991	1.075	1.075	1.075
1992	1.056	1.055	1.055
1993	1.000	0.999	1.001
1994	1.017	1.015	1.018
1995	0.993		

Table C17. Recreational fishery indices of abundance. SAW-23 n is number of anglers interviwed in each year (sample size). Nominal and GLM standardized indices include trips with bluefish catch and trips with zero bluefish catch but which targeted bluefish (SAW-18 CAT/TAR index definition; NEFSC 1994b). SSB index for ICA tuning is the product of the age 1 and older (SSB) percentage of the recreational catch, the SSB mean weight, and the GLM index.

Year	SAW-23 n	SAW-23 nominal index	SAW-23 GLM index	Percent age 1+	Mean weight of SSB (kg)	SSB index
1982	2,981	5.37	1.54	67.0	2.750	2.835
1983	4,768	3.80	1.15	84.1	2.542	2.466
1984	3,413	4.52	1.28	71.2	2.352	2.138
1985	6,828	5.36	1.38	79.6	2.066	2.271
1986	5,820	4.43	1.26	83.4	2.535	2.659
1987	5,843	4.61	1.33	89.1	2.523	2.995
1988	5,313	3.32	1.10	88.7	2.854	2.771
1989	10,372	4.14	1.21	78.3	2.391	2.257
1990	9,633	3.80	1.19	83.9	2.187	2.172
1991	10,618	3.42	1.07	79.7	1.610	1.380
1992	9,785	3.12	1.05	91.6	1.591	1.538
1993	7,565	2.70	1.00	86.7	2.180	1.890
1994	8,094	2.72	1.02	76.5	2.116	1.646
1995	7,287	2.37	0.99	91.1	2.059	1.863

Table C18. Total commercial landings and recreational catch at age for bluefish ('000). Lengths converted to age using NC DMF commercial fishery annual age-length keys.

	Age													
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
1982	11,280	9,853	2,879	2,462	806	1,230	1,187	822	681	867	125	64	41	32,297
1983	4,863	7,790	8,821	3,075	988	1,348	1,847	1,159	693	864	95	163	47	31,753
1984	7,288	6,940	6,825	2,088	917	760	813	777	561	878	84	95	48	28,074
1985	4,743	6,549	5,854	2,967	1,343	527	955	455	445	481	37	3	34	24,393
1986	5,269	8,195	8,882	2,866	1,080	1,737	1,235	1,064	1,209	995	60	0	0	32,592
1987	3,199	5,552	5,307	5,892	2,057	1,112	1,728	1,149	688	458	33	0	0	27,175
1988	1,749	2,131	2,578	1,629	2,033	1,638	877	969	426	337	168	9	28	14,572
1989	3,401	5,562	3,165	971	390	1,150	790	665	556	281	43	7	19	17,000
1990	2,807	7,426	1,910	713	394	442	1,155	443	525	398	7	7	4	16,231
1991	3,823	5,454	7,556	1,668	325	232	584	925	529	141	21	11	4	21,273
1992	2,163	9,731	1,776	2,459	609	488	183	330	329	158	6	6	2	18,240
1993	1,170	2,030	1,541	579	1,014	651	254	296	354	192	57	8	0	8146
1994	1,966	3,137	1,310	367	296	848	373	74	307	304	9	4	0	8995
1995	719	3,371	1,885	341	229	560	302	89	324	196	14	5	0	8035

Table C19. Total commercial landings and recreational catch mean weights at age (kg) for bluefish. Lengths converted to age using NC DMF commercial fishery annual age-length keys.

	Age													
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
1982	0.137	0.491	1.519	2.051	3.201	4.232	4.958	5.776	6.644	8.793	7.790	8.202	8.193	1.493
1983	0.095	0.421	0.988	2.147	3.162	4.417	5.577	6.211	6.862	8.901	8.363	7.903	8.365	1.907
1984	0.104	0.406	0.931	1.834	2.911	4.483	5.650	6.267	7.177	8.841	7.185	8.404	8.404	1.528
1985	0.103	0.399	0.965	1.926	2.819	3.991	5.053	6.119	6.819	8.361	8.326	7.473	7.812	1.460
1986	0.118	0.489	1.204	2.320	3.149	4.303	4.848	5.655	6.766	8.046	7.736	-	-	1.887
1987	0.117	0.296	1.180	2.022	2.959	3.927	4.984	5.885	6.500	8.574	7.812	-	-	2.012
1988	0.166	0.404	1.002	2.051	2.838	3.564	4.623	5.165	6.134	7.607	6.260	8.404	7.908	2.352
1989	0.125	0.296	1.059	2.118	3.638	4.106	4.720	5.513	6.096	7.724	7.820	7.229	8.206	1.595
1990	0.212	0.497	0.881	1.732	3.240	4.177	4.474	5.035	5.420	7.439	8.404	8.404	8.404	1.459
1991	0.136	0.333	0.701	1.732	2.808	3.963	4.965	5.746	6.052	7.695	7.667	7.553	8.033	1.182
1992	0.164	0.387	1.039	1.886	2.803	3.303	5.107	5.784	5.942	7.890	7.876	7.876	8.404	1.101
1993	0.175	0.587	0.951	2.458	2.731	3.237	4.880	6.267	6.465	7.153	6.556	5.571	8.404	2.005
1994	0.124	0.400	0.896	1.879	3.040	3.757	4.093	5.423	6.633	8.336	6.327	6.568	8.404	1.543
1995	0.168	0.436	0.982	1.734	2.849	4.058	4.696	5.652	6.393	7.019	6.435	6.711	-	1.034

Table C20. Stratified mean number per tow of bluefish from Cape Cod to Cape Hatteras (inshore strata 1-46) from NEFSC autumn inshore bottom trawl surveys.

Year	Mean	95% confidence interval		Coefficient of variation
		Low	High	
1974	9.830	5.335	14.326	25.3
1975	14.223	0.351	28.094	49.8
1976	43.944	26.723	61.164	20.0
1977	58.332	15.189	101.474	37.7
1978	14.550	11.105	17.995	12.1
1979	45.528	29.678	61.379	17.8
1980	37.605	13.482	61.729	32.7
1981	107.368	69.352	145.384	18.1
1982	34.246	15.066	53.425	28.6
1983	21.006	6.738	35.425	28.6
1984	59.841	39.575	80.108	17.3
1985	17.736	12.135	23.336	16.1
1986	40.748	-1.037	82.533	52.3
1987	7.444	2.958	11.933	30.8
1988	30.468	-16.489	77.424	78.6
1989	91.273	46.512	136.035	25.0
1990	9.321	5.099	13.543	23.1
1991	15.797	5.670	25.923	32.7
1992	17.865	14.467	21.264	9.7
1993	1.979	0.952	3.006	26.5
1994	12.379	8.636	16.123	15.4
1995	9.388	5.404	13.371	21.7

Table C21. Stratified mean weight per tow (kg) of bluefish from Cape Cod to Cape Hatteras (inshore strata 1-46) from NEFSC autumn inshore bottom trawl surveys.

Year	Mean	95% confidence interval		Coefficient of variation
		Low	High	
1974	1.475	0.783	2.166	23.9
1975	5.581	1.868	9.293	33.9
1976	5.724	3.765	7.682	17.5
1977	6.546	2.785	10.307	29.3
1978	5.875	4.843	6.906	9.0
1979	7.443	5.604	9.282	12.6
1980	7.031	2.430	11.633	33.4
1981	13.183	9.517	16.849	14.2
1982	4.823	2.484	7.161	24.7
1983	3.958	1.609	6.307	30.3
1984	7.682	5.960	9.404	11.4
1985	3.451	2.658	4.244	11.7
1986	3.913	1.860	5.966	26.8
1987	2.703	1.940	3.467	14.4
1988	1.982	0.379	3.585	41.3
1989	9.132	3.456	14.808	31.7
1990	2.513	1.488	3.358	20.8
1991	2.063	1.109	3.017	23.6
1992	1.363	0.931	1.795	16.2
1993	0.736	0.543	0.928	13.3
1994	1.673	1.071	2.275	18.4
1995	2.054	1.456	2.652	14.9

Table C22. Stratified mean number per tow of bluefish at age[1] from NEFSC autumn inshore bottom trawl surveys, Cape Cod to Cape Hatteras (strata 1-46).

	Age									
Year	0	1	2	3	4	5	6	7	8+	Total
1982	21.632	12.434	0.074	0.061	0.013	0.000	0.002	0.004	0.020	34.246
1983	6.654	13.566	0.687	0.028	0.003	0.014	0.023	0.011	0.021	21.006
1984	39.210	19.697	0.606	0.097	0.058	0.025	0.031	0.033	0.007	59.841
1985	10.770	5.981	0.570	0.264	0.059	0.022	0.026	0.018	0.010	17.736
1986	31.524	8.514	0.448	0.080	0.053	0.039	0.031	0.019	0.033	40.748
1987	1.996	4.670	0.346	0.150	0.069	0.032	0.073	0.044	0.030	7.444
1988	28.733	1.421	0.077	0.018	0.032	0.055	0.033	0.025	0.050	30.468
1989	51.015	40.007	0.130	0.026	0.008	0.031	0.026	0.018	0.012	91.273
1990	4.614	4.369	0.225	0.009	0.013	0.015	0.026	0.017	0.033	9.321
1991	8.856	6.603	0.210	0.089	0.026	0.007	0.001	0.001	0.000	15.797
1992	14.181	3.399	0.169	0.066	0.020	0.003	0.006	0.007	0.009	17.865
1993	1.564	0.259	0.080	0.026	0.024	0.012	0.003	0.008	0.002	1.979
1994	9.155	2.996	0.083	0.026	0.009	0.065	0.037	0.003	0.006	12.379
1995	5.119	3.939	0.245	0.015	0.001	0.029	0.023	0.005	0.013	9.388

[1]Aged using annual NC DMF age-length keys from NC commercial fisheries; 1994 NC DMF age-length keys used to age 1995 NEFSC lengths.

Table C23. Stratified mean number per tow of bluefish at age[1] from NEFSC autumn offshore bottom trawl surveys, Georges Bank to Cape Hatteras (offshore strata 1-25, 61-76).

	Age									
Year	0	1	2	3	4	5	6	7	8+	Total
1982	0.014	0.092	0.073	0.080	0.026	0.027	0.033	0.031	0.030	0.405
1983	0.016	0.030	0.081	0.106	0.024	0.028	0.035	0.017	0.011	0.347
1984	0.075	0.052	0.029	0.034	0.012	0.022	0.024	0.010	0.002	0.261
1985	0.115	0.272	0.318	0.069	0.032	0.034	0.061	0.012	0.015	0.928
1986	0.032	0.056	0.039	0.038	0.026	0.035	0.034	0.044	0.037	0.342
1987	0.001	0.007	0.018	0.053	0.056	0.032	0.083	0.066	0.032	0.347
1988	0.001	0.001	0.001	0.008	0.017	0.029	0.043	0.042	0.036	0.177
1989	0.397	0.685	0.001	0.001	0.004	0.019	0.017	0.016	0.011	1.151
1990	0.091	0.097	0.002	0.001	0.009	0.021	0.063	0.032	0.053	0.369
1991	0.001	0.009	0.013	0.026	0.007	0.001	0.003	0.025	0.018	0.104
1992	0.001	0.010	0.009	0.091	0.070	0.052	0.024	0.020	0.024	0.301
1993	0.000	0.000	0.000	0.052	0.102	0.020	0.010	0.024	0.012	0.219
1994	0.000	0.000	0.000	0.000	0.026	0.169	0.080	0.008	0.046	0.328
1995	0.082	0.156	0.038	0.078	0.006	0.100	0.063	0.013	0.042	0.578

[1]Aged using annual NC DMF age-length keys from NC commercial fisheries; 1994 NC DMF age-length keys used to age 1995 NEFSC lengths.

Table C24. Mean number per tow of bluefish at age from Connecticut trawl surveys (April-November). Fish aged by application of CT DEP age-length keys.

	Age									
Year	0	1	2	3	4	5	6	7	8+	Total
1984	38.41	0.59	0.56	0.22	0.04	0.01	0.02	0.01	0.00	39.86
1985	32.83	1.42	0.97	0.45	0.22	0.04	0.05	0.06	0.008	36.05
1986	31.45	1.97	1.27	0.30	0.19	0.10	0.04	0.02	0.006	35.35
1987	8.76	1.36	0.58	0.17	0.13	0.08	0.04	0.00	0.003	11.12
1988	10.64	0.69	0.46	0.29	0.19	0.14	0.08	0.003	0.003	12.50
1989	37.30	1.48	0.57	0.16	0.27	0.22	0.05	0.006	0.00	40.06
1990	23.79	2.97	0.63	0.09	0.12	0.17	0.02	0.00	0.00	27.79
1991	24.40	3.50	1.39	0.13	0.09	0.11	0.05	0.00	0.00	29.67
1992	24.30	3.32	1.73	0.17	0.15	0.28	0.005	0.00	0.00	29.96
1993	12.06	0.58	1.01	0.41	0.18	0.05	0.00	0.00	0.00	14.29
1994	28.75	1.35	0.72	0.49	0.37	0.24	0.01	0.00	0.00	31.93
1995	7.90	2.07	0.39	0.09	0.05	0.06	0.01	0.00	0.00	10.57

Table C25. Recruitment (age 0) indices for bluefish from State agency research surveys.

	Year																
State/gear	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
RI trawl	0.48	2.42	3.33	1.30	2.04	12.03	1.74	5.77	11.49	4.88	3.48	4.26	14.05	1.69	4.12	39.93	14.78
RI seine	-	-	-	-	-	-	-	1.36	24.9	12.8	16.5	27.3	20.1	5.4	2.2	26.8	4.4
NY Hudson	-	2.05	2.86	2.99	2.45	1.20	2.36	2.15	0.95	3.59	1.33	1.46	0.56	0.71	0.67	0.81	1.46
NY WLIS	-	-	-	-	-	-	-	24.8	77.6	5.0	21.6	7.2	10.3	8.8	2.8	2.8	3.4
NJ seine	-	-	-	-	-	-	-	-	-	45.4	58.3	25.7	11.5	11.8	3.6	37.2	11.9
DE trawl	-	0.04	0.00	0.04	0.04	0.06	0.05	0.17	0.13	0.23	0.63	0.14	0.18	0.08	0.08	0.14	0.14
MD seine	-	-	0.17	0.63	0.96	0.30	0.62	0.11	0.20	0.21	0.46	0.38	0.16	0.12	0.02	0.06	-
VIMS trawl	0.02	0.02	0.06	0.03	0.03	0.05	0.02	0.02	0.01	0.04	0.16	0.10	0.01	0.03	0.00	-	-
VINS seine	-	0.08	0.12	0.11	0.16	0.07	0.13	0.03	0.24	0.04	0.07	0.08	0.12	0.01	0.02	-	-
NC juv trawl	0.05	0.08	0.15	0.04	0.03	0.02	0.04	0.01	0.12	0.07	0.30	0.07	0.07	0.01	0.03	0.02	-
NC Pamlico trawl	-	-	-	-	-	-	-	-	0.20	0.19	0.33	0.36	0.41	0.26	0.26	0.42	-

Table C26. Mean number per seine haul of age 0 bluefish (less than or equal to 25 cm) and age 1 and older bluefish (greater than 25 cm) from NJ BMF trawl survey in ocean waters (August and October tows).

Year	Age 0	Age 1+
1988	45.40	5.83
1989	58.28	3.47
1990	25.71	3.41
1991	11.50	1.50
1992	11.76	1.78
1993	3.60	0.48
1994	37.22	1.25
1995	11.93	1.90

Table C27. SAW-23 bluefish ICA model results.

Fishing mortality

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
0	.1690	.0816	.1017	.0970	.1541	.1228	.0505	.0584	.1075	.1942	.1113	.1047	.0813	.0877
1	.1881	.1768	.1699	.1346	.2552	.2548	.1174	.2359	.1843	.3297	.5138	.4833	.3750	.4045
2	.1284	.2701	.2464	.2262	.2874	.2746	.1911	.2743	.1240	.3116	.3192	.3003	.2330	.2513
3	.1635	.2069	.0992	.1707	.1721	.3316	.1332	.1067	.0950	.1601	.1366	.1285	.0997	.1075
4	.0535	.0960	.0924	.0909	.0901	.1899	.1922	.0452	.0604	.0597	.1029	.0968	.0751	.0810
5	.1317	.1253	.1050	.0739	.1709	.1326	.2413	.1669	.0693	.0485	.1658	.1559	.1210	.1305
6	.1776	.3136	.1093	.1945	.2613	.2676	.1559	.1834	.2670	.1278	.0891	.0838	.0650	.0702
7	.2372	.2766	.2227	.0863	.3648	.4314	.2529	.1775	.1574	.3674	.0756	.0711	.0552	.0596
8	.2469	.3398	.2212	.2019	.3618	.4445	.3001	.2335	.2210	.2923	.2056	.1934	.1501	.1618
9	.2469	.3398	.2212	.2019	.3618	.4445	.3001	.2335	.2210	.2923	.2056	.1934	.1501	.1618

Numbers at age (millions)

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
0	81	68	82	57	41	30	39	65	30	24	19	13	24	14	14
1	64	53	49	58	40	27	21	29	48	21	15	13	9	17	10
2	27	41	35	32	39	24	16	14	18	31	12	7	6	5	9
3	18	18	24	21	20	23	14	11	9	12	18	7	4	4	3
4	17	12	12	17	14	13	13	10	7	6	8	12	5	3	3
5	11	13	9	8	12	10	8	8	7	5	4	6	9	3	2
6	8	8	9	6	6	8	7	5	5	5	4	3	4	6	2
7	4	5	4	6	4	4	5	4	3	3	4	3	2	3	4
8	3	3	3	3	4	2	2	3	3	2	2	3	2	2	2
9	1	3	3	4	4	5	3	3	4	4	4	3	4	4	4

Table C27. (Continued)

Stock summary						
Year	Recruits $x10^6$	Total B mt	Spawn B mt	Landings mt	Y/SSB	Ref. F age 1
1982	81	324,337	278,212	43,082	0.1549	0.1881
1983	68	324,221	286,026	48,416	0.1693	0.1768
1984	82	304,592	267,344	36,675	0.1372	0.1699
1985	57	301,144	265,372	30,462	0.1148	0.1346
1986	41	328,864	292,985	50,134	0.1711	0.2552
1987	30	278,570	252,305	41,542	0.1646	0.2548
1988	39	218,711	194,086	30,068	0.1549	0.1174
1989	65	213,598	188,016	23,439	0.1247	0.2359
1990	30	198,881	168,811	21,035	0.1246	0.1843
1991	24	181,206	162,837	22,350	0.1373	0.3297
1992	19	172,679	155,773	17,187	0.1103	0.5138
1993	13	156,944	141,043	14,655	0.1039	0.4833
1994	24	138,553	125,191	12,153	0.0971	0.3750
1995	14	124,024	110,322	10,601	0.0887	0.4045

Table C28. Thompson and Bell (1934) yield-per-recruit analysis for bluefish: 1992-1995 arithmetic mean weights at age, ICA 1992-1995 PR vector.

Proportion of F before spawning: 0.2500
Proportion of M before spawning: 0.5000
Natural mortality is constant at: 0.250
Initial age is: 0; Last age is: 12
Last age is a plus group;

Age	Fish mort pattern	Nat mort pattern	Proportion mature	Average stock	Weights catch
0	0.2200	1.0000	0.0000	0.133	0.133
1	1.0000	1.0000	0.5000	0.424	0.424
2	0.6200	1.0000	1.0000	0.958	0.958
3	0.2700	1.0000	1.0000	1.928	1.928
4	0.2000	1.0000	1.0000	2.930	2.930
5	0.3200	1.0000	1.0000	3.671	3.671
6	0.1700	1.0000	1.0000	4.581	4.581
7	0.1500	1.0000	1.0000	5.622	5.622
8	0.4000	1.0000	1.0000	6.296	6.296
9	0.4000	1.0000	1.0000	6.500	6.500
10	0.4000	1.0000	1.0000	6.813	6.813
11	0.4000	1.0000	1.0000	6.900	6.900
12+	0.4000	1.0000	1.0000	8.404	8.404

Slope of the Yield/Recruit Curve at F = 0.00: --> 3.1937

F level at slope = 1/10 of the above slope ($F_{0.1}$): -----> 0.312
Yield/Recruit corresponding to $F_{0.1}$: -------> 0.4151

F level at 30 % of Max Spawning Potential (F_{30}): -----> 0.422
SSB/Recruit corresponding to F_{30}: ----------> 2.7041

F level to produce Maximum Yield/Recruit (F_{MAX}): ---- --> 0.469
Yield/Recruit corresponding to F_{MAX}: -------> 0.4368

F level at 20 % of Max Spawning Potential (F_{20}): -------> 0.586
SSB/Recruit corresponding to F_{20}: ----------> 1.8027

Table C28. (Continued)

	FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	% MSP
	0.000	0.00000	0.00000	4.5208	10.5128	2.7635	9.0145	100.00
	0.050	0.08111	0.13620	4.1983	9.0347	2.4688	7.6795	85.19
	0.100	0.15115	0.23423	3.9201	7.8144	2.2154	6.5812	73.01
	0.150	0.21212	0.30433	3.6785	6.7980	1.9960	5.6693	62.89
	0.200	0.26551	0.35384	3.4672	5.9447	1.8048	4.9064	54.43
	0.250	0.31255	0.38806	3.2814	5.2236	1.6372	4.2636	47.30
	0.300	0.35420	0.41090	3.1173	4.6104	1.4897	3.7190	41.26
$F_{0.1}$	0.312	0.36364	0.41509	3.0801	4.4749	1.4564	3.5989	39.92
	0.350	0.39123	0.42523	2.9717	4.0864	1.3594	3.2550	36.11
	0.400	0.42430	0.43323	2.8420	3.6365	1.2437	2.8578	31.70
$F_{30\%}$	0.422	0.43750	0.43514	2.7903	3.4619	1.1978	2.7041	30.00
	0.450	0.45394	0.43650	2.7260	3.2484	1.1407	2.5164	27.92
F_{MAX}	0.469	0.46443	0.43677	2.6850	3.1147	1.1045	2.3990	26.61
	0.500	0.48060	0.43627	2.6220	2.9126	1.0488	2.2219	24.65
	0.550	0.50464	0.43347	2.5285	2.6209	0.9665	1.9669	21.82
$F_{20\%}$	0.586	0.52069	0.43024	2.4662	2.4324	0.9119	1.8027	20.00
	0.600	0.52640	0.42882	2.4441	2.3666	0.8926	1.7455	19.36
	0.650	0.54615	0.42285	2.3678	2.1445	0.8261	1.5526	17.22
	0.700	0.56411	0.41598	2.2986	1.9498	0.7661	1.3841	15.35
	0.750	0.58050	0.40852	2.2357	1.7787	0.7119	1.2366	13.72
	0.800	0.59549	0.40071	2.1783	1.6280	0.6628	1.1071	12.28
	0.850	0.60924	0.39273	2.1260	1.4950	0.6182	0.9932	11.02
	0.900	0.62187	0.38472	2.0780	1.3773	0.5777	0.8929	9.90
	0.950	0.63350	0.37679	2.0340	1.2730	0.5407	0.8042	8.92
	1.000	0.64424	0.36900	1.9936	1.1803	0.5070	0.7258	8.05

Table C29. Input parameters and projection results for bluefish: landings and stock biomass ('000 mt). Starting stock sizes on 1 January 1995 are as estimated by the SAW-23 ICA model. Mean weights at age (stock biomass, landings) are arithmetic means of 1992-1995 values. Fishing mortality in 1996 was assumed to continue at the level estimated for 1995, F = 0.40. The short-term average (1992-1995) recruitment was assumed for 1996-1998 (geometric mean recruitment for 1992-1995 of 17.0 million age 0 fish). Projections are made for several levels of fishing mortality rates during 1997-1998: F_{95} = 0.40, F_{95} = 0.40 with the catch of age 0 fish eliminated in 1997-2000 (F at age 0 = 0.0), $F_{20\%}$ = 0.59, $F_{30\%}$ = 0.42, F_{MSY} = 0.20, and F in 1997-2000 which stabilizes SSB (F_{STAB} = 0.06). Proportion of F and M before spawning = 0.25 (spawning peak at 1 April). Partial recruitment vector and landings include recreational discard with a 15% hooking mortality rate.

Age	Stock size in 1995 ('000)	Fishing mortality pattern	Proportion mature	Mean weights landings (kg)
0	13,890	0.22	0.00	0.133
1	17,473	1.00	0.50	0.424
2	4,778	0.62	1.00	0.958
3	3,945	0.27	1.00	1.928
4	2,860	0.20	1.00	2.930
5	3,306	0.32	1.00	3.671
6	5,877	0.17	1.00	4.581
7	2,763	0.15	1.00	5.622
8	1,548	0.40	1.00	6.296
9+	3,992	0.40	1.00	7.475

Recruitment in 1996-1998 = geometric mean for 1992 -1995: 16,973 age 0 fish ('000)

	1996			1997			1998		
Option	F_{96}	Land	SSB	F_{97}	Land	SSB	F_{98}	Land	SSB
F_{95}	0.40	12.1	91.2	0.40	12.0	81.1	0.40	10.9	72.7
F_{95} (no F on age 0)	0.40	12.1	91.2	0.40	11.8	81.1	0.40	10.9	72.8
$F_{20\%}$	0.59	12.1	91.2	0.59	17.0	79.8	0.59	14.4	66.5
$F_{30\%}$	0.42	12.1	91.2	0.42	12.5	81.0	0.42	11.3	72.0
F_{MSY}	0.20	12.1	91.2	0.20	6.2	82.5	0.20	6.5	79.9
F_{STAB}	0.06	12.1	91.2	0.06	1.9	83.6	0.06	2.0	85.4

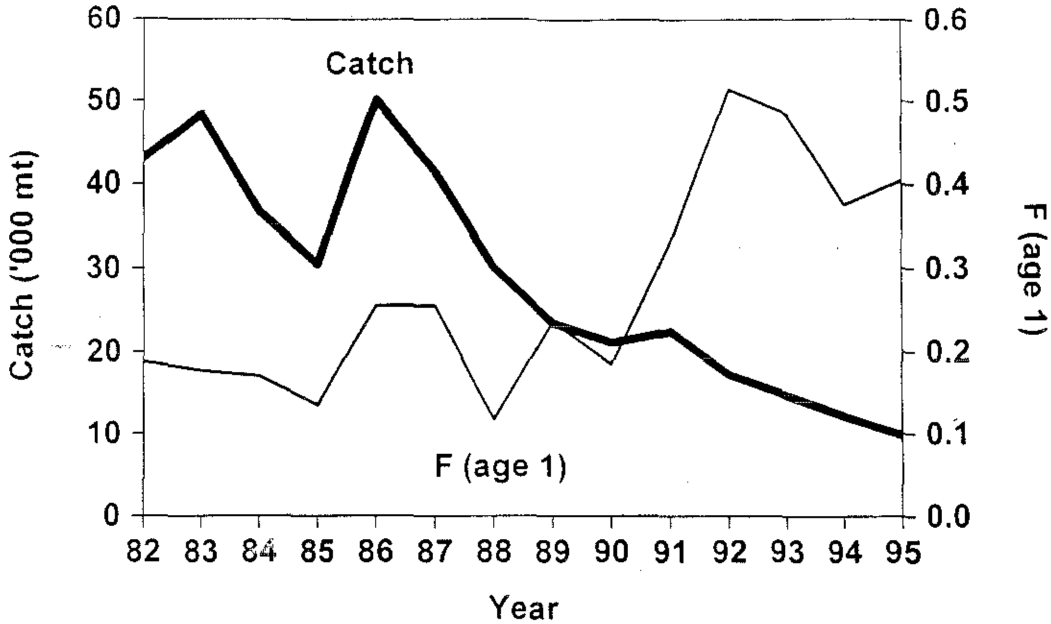

Figure C1. Total catch (total landings and recreational fishery discards, thousands of mt) and fishing mortality rate (fully-recruited F, age 1) for bluefish.

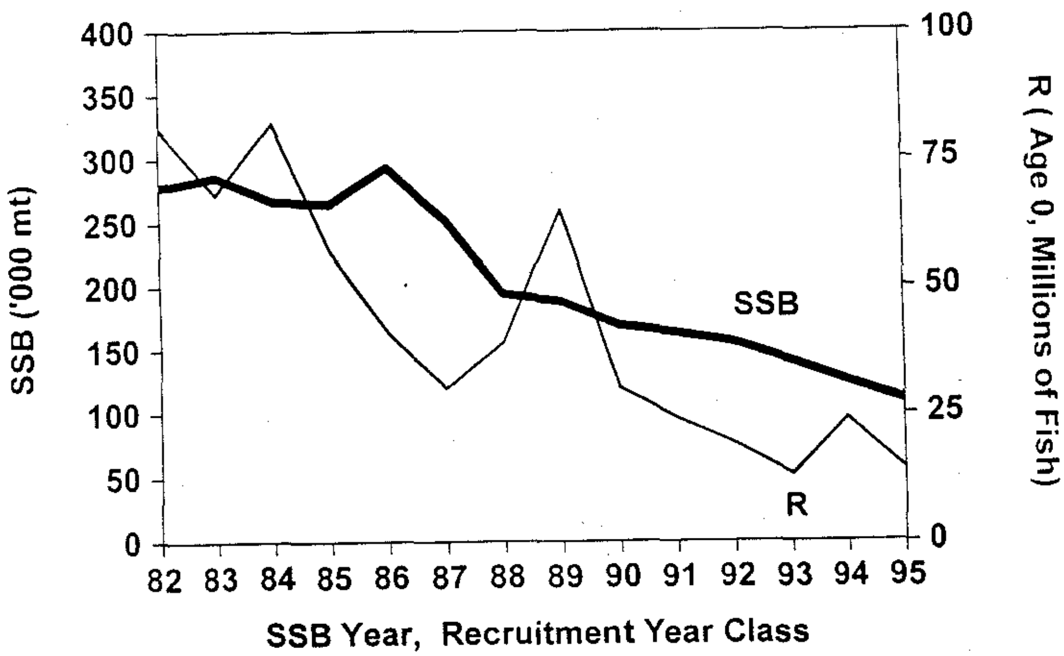

Figure C2. Spawning stock biomass (SSB ages 1-9+, thousands of mt) and recruitment (millions of fish at age 0) for bluefish.

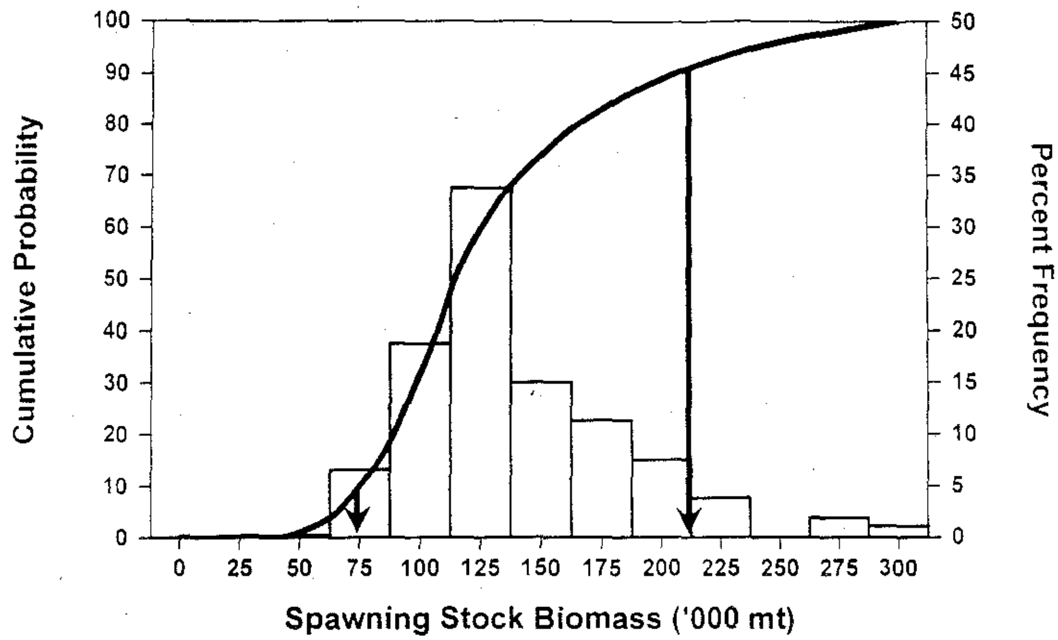

Figure C3. Precision of the estimate of spawning stock biomass (SSB) on April 1, 1995 for bluefish. Vertical bars display the probability distribution of SSB given the precision of the point estimate. The solid line gives the probability that SSB is less than any value along the X axis.

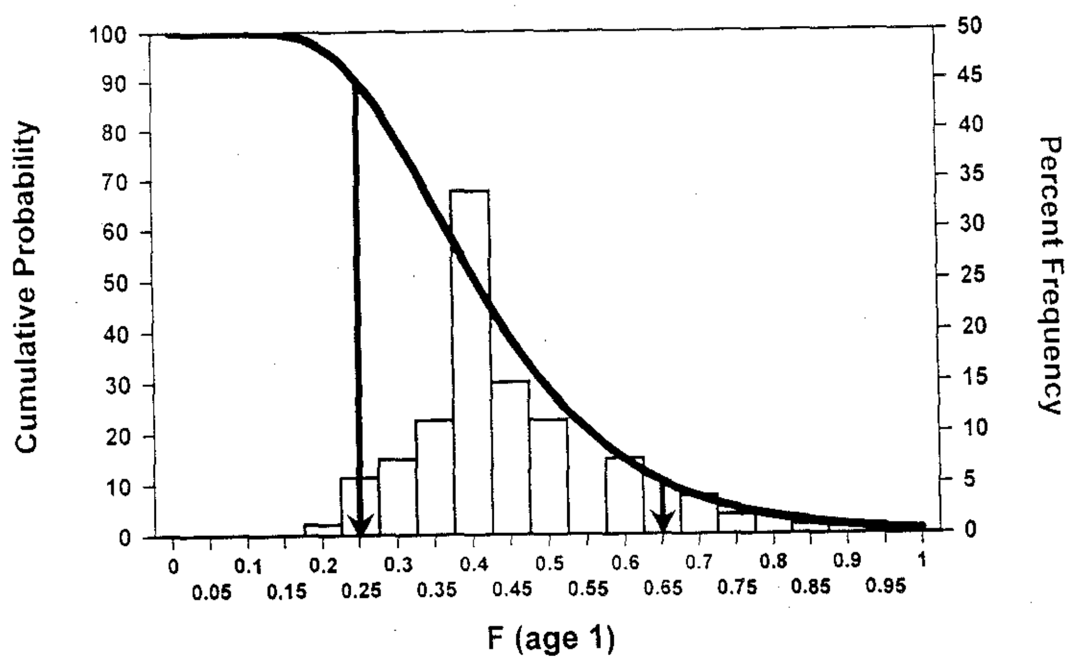

Figure C4. Precision of the estimate of fully-recruited F (age 1) in 1995 for bluefish. Vertical bars display the probability distribution of F given the precision of the point estimate. The solid line gives the probability that F is greater than any value along the X axis.

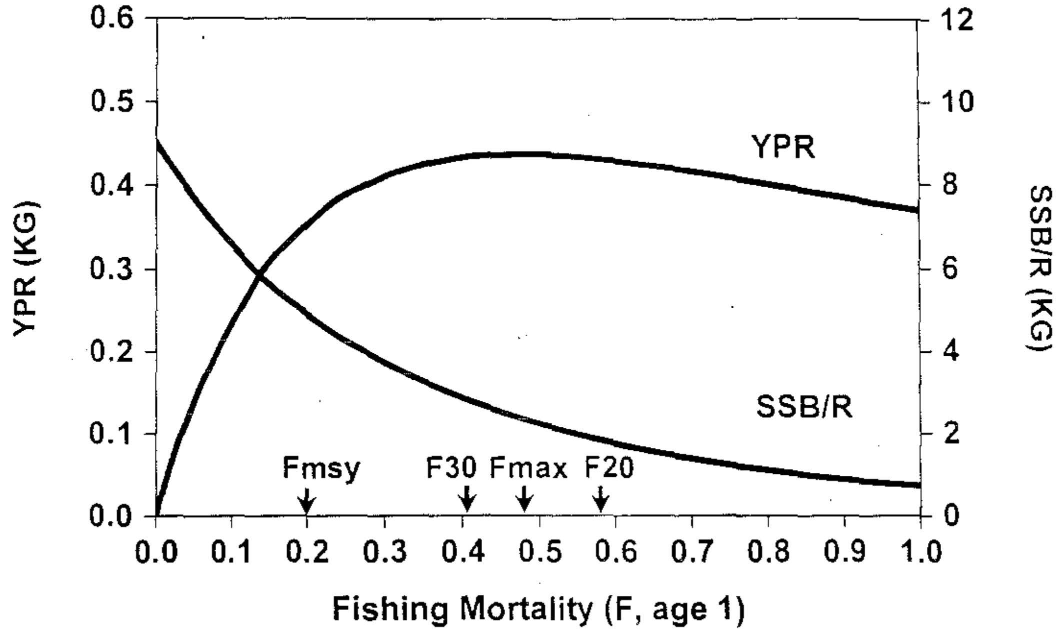

Figure C5. Yield per recruit (YPR) and spawning stock biomass per recruit (SSB/R) for bluefish.

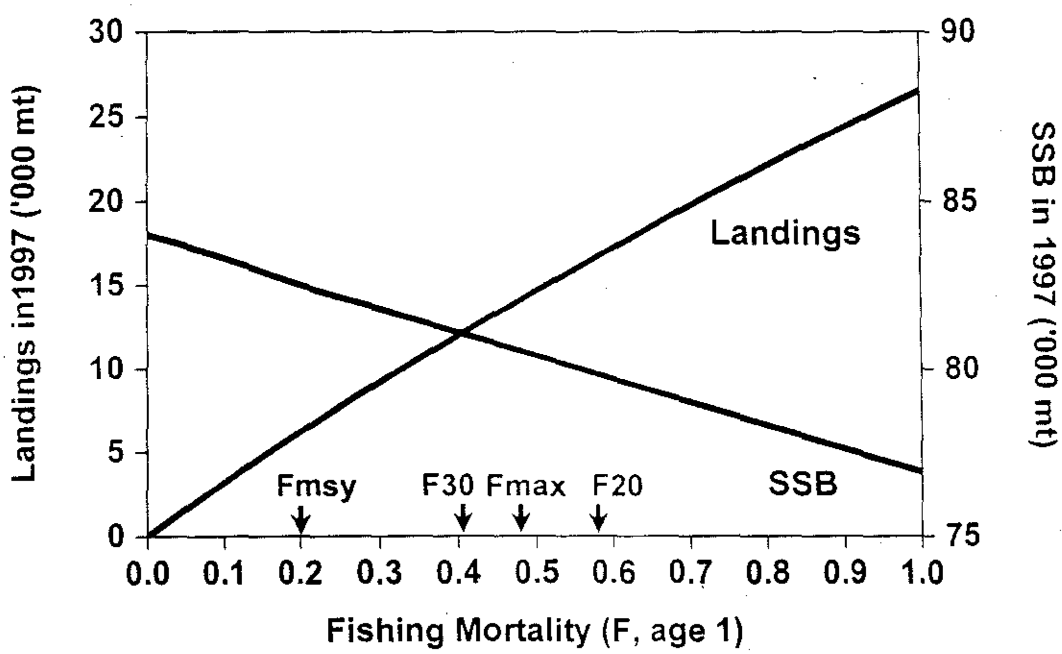

Figure C6. Forecast landings and spawning stock biomass (SSB) in 1997 of bluefish over a range of fishing mortalities from F = 0.0 to F = 1.0.